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AMERICAN DYESTUFF REPORTER

Official Journal

The Estimation of Amino Nitrogen in Insoluble Proteins

HENRY A. RUTHERFORD, MILTON HARRIS and ARTHUR L. SMITH*

I. INTRODUCTION

THE basic amino acids, arginine, lysine and histidine, which are of primary importance in proteins appear to be held in the protein chains by peptide linkages involving their carboxyl and α-amino groups. Presumably, the remaining basic groups are free in the native protein and as a result, they have been related to the combining of various proteins with acids, dyes, and tannins. Completely satisfactory conclusions on the nature of such combinations have not been obtained because of the lack of suitable methods for the quantitative estimation of the free amino groups in proteins and especially those in insoluble proteins.

An apparatus is described for determining the rate of evolution of nitrogen from proteins and other amino compounds during treatment with nitrous acid. Examination of the rate curves of a number of proteins indicates that there is a primary reaction with a relatively rapid evolution of nitrogen followed by a secondary reaction with a much slower evolution of nitrogen in which the rate is approximately constant. Extrapolation of the straight line portions of the curves in zero time gives values which appear to be good estimates of the amino nitrogen contents of the proteins.

The Van Slyke method[1] which has been used for the determination of amino nitrogen in solutions of amino acids, peptides, etc., has limitations which have frequently been discussed[2, 3]. Its application to proteins, and more especially insoluble proteins, is further limited because of the difficulty of preparing solutions of these materials without chemical degradation.

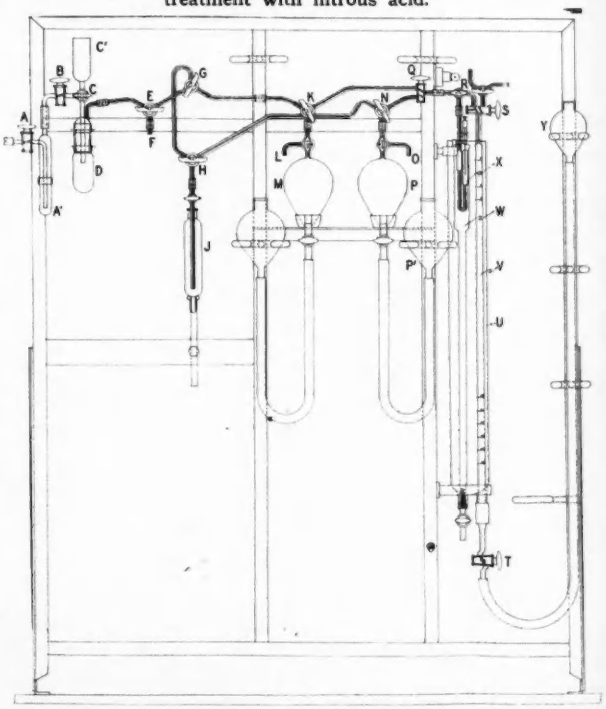
In a previous investigation, Kanagy and Harris[4] avoided such degradation by working with suspensions of powdered wool and collagen. It was shown that when these proteins are treated with nitrous acid, increasing amounts of nitrogen are evolved with increasing duration of treatment. The amount of nitrogen evolved in any arbitrary length of time does not necessarily represent the amino nitrogen content of the protein in question. The rate of evolution of nitrogen from the protein, however, appeared to be significant since it indicated a primary and a secondary reaction.

The method previously employed for the determination of the rate of evolution of nitrogen was time-consuming since a Van Slyke apparatus was used, which necessitated a separate determination for each period of time. In addition, it was difficult to prepare sufficiently uniform suspensions to assure the addition of an accurately known amount of protein for each determination. In order to eliminate these objections, an apparatus which requires only one sample to obtain a curve which represents the rate of evolution of nitrogen, was developed. A description of the apparatus and a number of preliminary results obtained with it are reported in the present paper.

II. APPARATUS AND TECHNIQUE OF OPERATION

The apparatus which was developed for this investigation is shown in figure 1. An excellent, detailed description of the construction, assembly, and manipulation of the distributor EGKQNH, the bubbling pipette

Fig. 1—Apparatus for determining the rate of evolution of nitrogen from proteins and other amino compounds during treatment with nitrous acid.



*Research Associates at the National Bureau of Standards representing the American Association of Textile Chemists and Colorists. This work was aided by grants from the Textile Foundation, Inc., the Chemical Foundation, Inc., and the Eavenson and Levering Company.

J, the water jacket U, the manometer X, the compensator W, and the burette V is given by Sheperd[5] in a comprehensive paper on apparatus for the analysis of gas mixtures.

The bubbling pipette J is filled with a saturated solution of potassium permanganate, approximately 0.5 N with respect to potassium hydroxide. The absorption bulb P, which has a capacity of 500 ml., contains 300 ml. of a potassium hydroxide solution* (prepared by adding 3 volumes of water to 5 volumes of a saturated solution of potassium hydroxide), over mercury. The sampling bulb M is filled with mercury to stopcock K. The distributor, and the arm of the manometer X connected thereto, are filled with oxygen-free nitrogen[5]. The burette V has a capacity of 25 ml. and is calibrated to 0.05 ml. Readings are readily estimated to 0.01 ml. The leveling bulb Y contains enough mercury to completely fill the burette and leave an excess within the bulb.

At the beginning of an analysis the entire distributor as well as approximately 10 ml. of the burette is filled with nitrogen[5]. The alkaline permanganate solution in J is adjusted to the etch-marks on the capillary stems, the mercury in M to stopcock K, and the potassium hydroxide solution in P to a mark just above the bulb. The pressure within the distributor, manometer and burette is balanced against that in the compensator[5], the volume of gas in the burette is recorded, and the temperature of the water bath surrounding the compensator and burette is noted.

The sample to be analyzed is placed in the reaction vessel D, which has a capacity of approximately 70 ml. Obviously, the size of the sample to be used will depend on its amino nitrogen content and the capacity of the burette. If the material to be analyzed is water-soluble, 10 ml. of the solution is taken. If the material is insoluble, a known weight is placed in the reaction flask and thoroughly wet out with 10 ml. of water saturated with carbon dioxide. The ground glass joint of the reaction vessel is properly greased[5], placed in position, and securely fastened with rubber bands. The air in the reaction vessel is swept out with pure carbon dioxide, which enters through stopcock A, and passes through a bubbling tube A^1 for the purpose of regulating the flow of carbon dioxide, and finally out at F. Ten minutes is usually ample time for removal of the air and, after this time, a sample of gas may be taken through the apparatus by the following procedure, to determine whether all of the air has been removed. The stopcocks are set so that the gas may pass from D to M, a 500-ml. sample of carbon dioxide is taken into bulb M through ABDGK, and stopcock B is closed. The gas in M is then passed to the bulb P through K, G, H, and N. The capillary from K to N is then swept out with nitrogen from the burette through SRQKGHN to the bulb P. Practically all of the carbon dioxide is immediately taken up by the solution of potassium hydroxide. The last traces of cabon dioxide are removed by repeated passing of the gas from P into the bubbling pipette J, and back to P, three such passages being sufficient to remove measurable amounts of carbon dioxide. During analyses, oxides of nitrogen are formed from the spontaneous decomposition of the nitrous acid. These are removed by the alkaline permanganate solution in J, five of the passages described above being used. The residual gas, which is nitrogen, is then taken into the burette. The burette is opened to the manometer, the pressure within the distributor and the burette adjusted to the pressure of the compensator[5], the temperature of the water bath noted, and the increase in volume of nitrogen is determined. As a check the gas in the burette is again passed through the postassium permanganate and potassium hydroxide solutions and the volume again determined.

The procedure outlined above is followed for a regular analysis. Since the rate of reaction is markedly affected by temperature, all experiments were done in a constant temperature room at 22° C. The nitrous acid solution, the preparation of which is described later, is added to the sample through C^1 by opening D to bulb P and slightly lowering the level of the solution in P. The measurement of the amount of gas evolved at any time is accomplished as follows. One and one-half minutes before taking a sample of gas, a partial vacuum is created in the reaction flask by lowering the leveling bulb P^1. The reaction flask D, which is attached to the distributor by means of rubber connections, is shaken for an arbitrary[4] but definite time (45 seconds in this work). A 500-ml. sample of gas is then taken by passing carbon dioxide through D until M is filled, and the amount of nitrogen is determined as previously described. The sampling, purification, and determination of the volume of the residual gas require approximately 7 minutes.

III. RESULTS AND DISCUSSIONS

1. The decomposition of nitrous acid.

As was previously pointed out[4], one of the possible sources of error in the Van Slyke method is the correction for relatively large amount of nitrogen which may be evolved by the spontaneous decomposition of the nitrous acid. It was shown that the size of the blank depends on the age of the sodium nitrite solution, on the amount of mechanical action, and on the nature of the material being analyzed. Since the amount of free amino nitrogen is often very small, it was particularly desirable to keep the blank corrections as small as possible.

A preliminary investigation indicated that in addition to the above-mentioned factors, the size of the blank increases considerably with decreasing pH of the solution. Furthermore when the pH of the solution of nitrous acid was increased, there was a decrease in the rate at which

* Solutions were saturated with nitrogen at atmospheric pressure.

nitrogen was evolved from an amino compound. As a result, it was necessary to seek those conditions which would give a sufficiently rapid evolution of nitrogen and as small a blank as possible.

Sodium acetate, because of its buffering action was found to be very effective in decreasing the size of the blanks. Raising the pH of the nitrous acid solution from pH 3.4 to pH 4 by the addition of suitable amounts of sodium acetate decreased the blank by approximately 80 per cent. In order to study the effect of sodium acetate on the rate of evolution of amino nitrogen, the experiments recorded in table 1 were performed. The results

TABLE 1.

Rates of evolution of nitrogen from alanine in solutions in which the proportion of nitrous acid and sodium acetate were varied.

Exp. No.	*Glacial Acetic Acid*	*Sodium Nitrite*	*Saturated Sodium Acetate†*	*Water‡*	*Time*	*Total N as amino nitrogen*
	ml.	*gms.*	*ml.*	*ml.*	*min.*	*%*
1	3	12	10	30	15	81.2
					30	84.4
2	5	12	10	25	15	92.8
					30	97.9
3*	5	12	10	25	15	69.4
					30	85.4
4	5	6	10	25	15	93.7
					30	97.9
5	2.5	3	10	25	15	58.8
					30	84.3
6	2.5	3	—	35	15	92.8
					30	99.1
7	5	6	5	30	15	96.2
					30	101
					45	101
8	5	6	—	35	15	99
					30	101
					45	101

* Reaction flask not shaken before sampling.
† Saturated aqueous solution at 22° C.
‡ Volume given includes 10 ml. in which alanine was dissolved.

show that of the combination of nitrous acid and sodium acetate tried, that given in experiment number 7 was the most effective.

The nitrous acid solution used in subsequent experiments was prepared as follows. Five ml of glacial acetic acid was mixed with 5 ml. of a saturated solution of sodium acetate. Six grams of sodium nitrite was dissolved in 20 ml. of water previously saturated with CO_2, the two solutions were mixed, gently stirred, and then poured into the funnel C[1]. Exactly 1½ minutes after mixing the two solutions, the solution is allowed to run into the reaction vessel D as previously described.

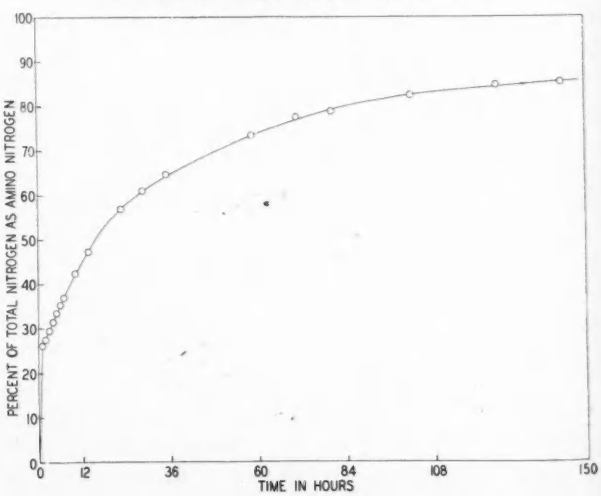
2. Estimation of amino nitrogen.

An examination of the literature pertaining to the Van Slyke method and its limitations[1,2,3] shows that many amino acids, peptides, and related compounds give faulty values when analyzed for amino nitrogen content. A confirmation of some of those findings was obtained during the present work with various amino acids. In view of such abnormalities, it would appear at first sight to be a discouraging task to attempt to estimate the amino nitrogen content of an insoluble protein. Although exact mechanisms to account for the abnormal behavior of many compounds are not known, it is quite certain that in most cases, the extra nitrogen is not formed by the reaction of nitrous acid with the expected end-product of the reaction[3]. The complexity of the reactions suggests that the extra nitrogen might be formed by a series of reactions, probably involving more than one intermediate product. From this standpoint, it appears possible that insoluble proteins may be less abnormal than the less complex soluble compounds which are free to move about in solution and enter into a number of different reactions.

Of the various amino acids which give high values for amino nitrogen, only tryptophane and arginine evolve nitrogen at an appreciable rate during their secondary reactions. The remaining amino acids exhibit a rapid primary evolution of nitrogen which gives values over 100 per cent, based on the theoretical content of amino nitrogen, in 5 minutes or less. They may or may not exhibit a very small increase in the amount of nitrogen evolved after this time. Since wool and collagen contain little if any tryptophane but relatively large amounts of arginine, an attempt was made in a previous investigation[4] to relate the arginine content of the protein to the rate of evolution of nitrogen during the secondary reaction.

The reaction of arginine with nitrous acid was reinvestigated with the new apparatus. Some preliminary results are shown in figures 2 and 3. Assuming that all of the nitrogen evolved (other than that corrected for in the blank) comes from the arginine, the curve in figure 2 shows that nearly 90 per cent of the total nitrogen of arginine is liberated in about 150 hours. A closer examination of the first part of the curve, as shown in figure 3,

Fig. 2—The rate of evolution of nitrogen during the continued treatment of arginine with nitrous acid.



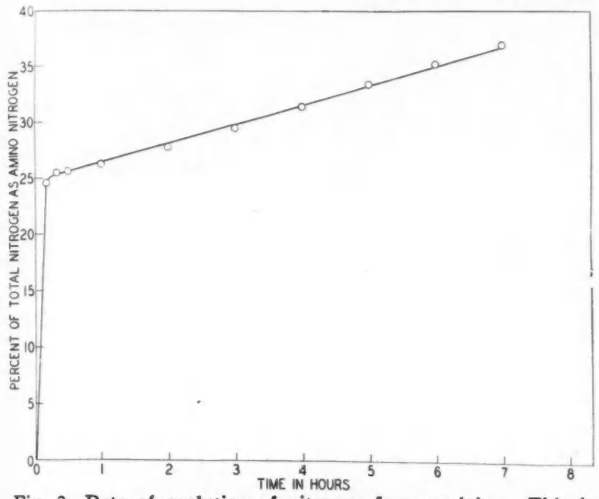


Fig. 3—Rate of evolution of nitrogen from arginine. This is the initial portion of the curve shown in Fig. 2 plotted on a larger scale.

reveals that a rapid evolution of nitrogen which is called the primary reaction occurs in the first few minutes, followed by a much slower secondary reaction in which the rate of evolution of nitrogen is approximately constant. Extrapolation of the secondary portion of the curve (fig. 3) to zero time gives a value of 25 per cent, which is equal to the α-amino nitrogen content of arginine. When the concentration of arginine in the reaction mixture was varied, as shown in table 2, the experimental values for

TABLE 2.

Determination of the α-amino-nitrogen content of arginine hydrochloride by the extrapolation method.

Arginine	*Amino nitrogen*		*Slope of*
mg.	*theoretical**	*experimental*	*curve*
hydrochloride	*mg.*	*mg.*	*mg. nitrogen/hour*
50.0	3.22	3.17	0.24
25.1	1.63	1.64	.13
12.5	0.81	0.82	.06

* Calculated from analyses by the Kjeldahl method.

the α-amino nitrogen content, obtained by extrapolation of the secondary portions of the curves, are in very good agreement with the theoretical values. It is also of interest to note that for the given concentration of nitrous acid the slopes of the curves (and the rate of evolution of nitrogen) are directly proportional to the initial concentrations of arginine. However, when the arginine content is kept constant and the concentration of nitrous acid is cut to half the usual value, the rate of evolution of nitrogen in the secondary reaction is very much lower, although the extrapolated value for amino nitrogen is the same.

In the previous investigation[4] it was suggested that the arginine content of an insoluble protein could be estimated by determining the relative rates of evolution of nitrogen from the guanidine nuclei in a protein and in arginine. If this is true, then the decrease in rate of evolution of nitrogen from a protein during the secondary reaction, with decrease in concentration of nitrous acid, should be proportional to the decrease in the rate of evolution of nitrogen from arginine under similar conditions. That this suggestion is not valid is shown in table 3. The

TABLE 3.

Effect of varying the concentration of nitrous acid on the rates of evolution of nitrogen during the secondary reactions.

	Slope	
	2.1 *M* HNO_2	1.05 *M* HNO_2
Wool	.16	.13
Arginine	1.86	.36

results indicate that the agreement between the calculated values for the arginine contents of wool and collagen and those obtained by isolation methods was the result of chance coincidence.

The good agreement between the known α-amino nitrogen content of arginine and the value obtained by the extrapolation method (figure 3) suggested that the amino nitrogen content of a protein might also be estimated by that method. The results of determinations of the rates of evolution of nitrogen from a number of proteins (figure 4) show that there is a rapid evolution of

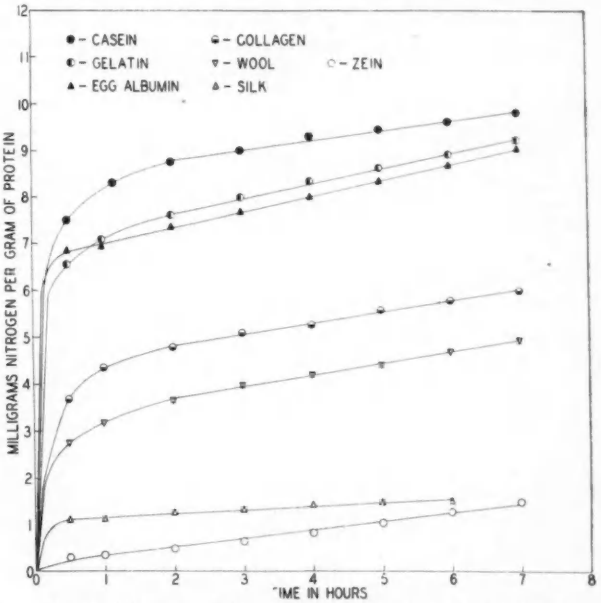


Fig. 4—The rates of evolution of nitrogen from various proteins.

nitrogen up to about 2 hours, after which there is a very much slower evolution of nitrogen in which the rate is approximately constant. The duration of the treatments was about 7 hours.

Extrapolation of the straight line portions of the curves

to zero time give the values* shown in the first two columns of table 4. Whether or not the extrapolated values gives a good estimate of the amino nitrogen content may appear questionable, but there seems to be a certain amount of justification in the procedure as shown by the relationship of the extrapolated values to the calculated values, based on the lysine contents of the protein. Van Slyke and Birchard[6] in their early studies on native proteins suggested that the amino nitrogen content of a protein should be closely related to the number of ε-groups of lysine in the protein. On the basis of such a relationship, it is to be expected that calculation of the lysine contents from the amino nitrogen values (obtained by the extrapolation method) would give higher values than those found experimentally by isolation methods, since the latter are known to give low results. A comparison of the calculated and experimental values is shown in the last two columns in table 4. Except in the case of gelatin the calculated values for the lysine content are higher than the lysine content as found by isolation methods by a roughly constant amount.

TABLE 4.

Free-amino-nitrogen content of various proteins as obtained by the extrapolation method. The values for lysine in the last two columns represents those calculated from the amino nitrogen contents and those recorded in the literature as obtained by isolation methods.

Protein	*Free amino-nitrogen*		*% Lysine*	
	% of total N	*mg. N/gm. of protein*	*Calculated*	*Literature*
Zein	0.08	0.12	0.12	0.0 [7]
Silk	0.56	1.05	1.10	0.25 [8]
				0.85 [9]
Wool	1.94	3.16	3.3	2.3 [10]
Collagen ...	2.37	4.26	4.5	2.75[11]
Egg albumen ..	4.50	6.75	7.1	4.97[12]
Gelatin	4.67	7.03	7.3	2.75[11]
Casein	5.68	8.36	8.7	6.5 [13]

Although collagen and gelatin are presumably the same protein (the gelatin was prepared from a sample of the collagen used for these analyses), they give different values for amino nitrogen by the extrapolation method. The higher value obtained for gelatin may be the result of liberation of groups during the conversion of the insoluble collagen to soluble gelatin which react with nitrous acid to form nitrogen. It is also possible that the differences are simply dependent on the state of aggregation of the protein.

Unfortunately, the analytical data obtained by isolation methods are not sufficiently accurately to rigidly test the validity of the extrapolation method. However, in the cases of crystalline egg albumin and collagen, data obtained by very different methods afford an opportunity for a comparison.

Kekwick and Cannan[14], from determinations of the hydrogen ion dissociation curves of crystalline egg albumin, concluded that the egg albumin molecule contains 16-18 amino groups which they tentatively identified as the ε-amino groups of lysine. They also found that the lysine nitrogen of the phosphotungstate fraction of the hydrolyzed protein corresponded to 17-18 molecules of lysine per molecule of egg albumin. Calculation of the lysine content from the value in table 4 indicated the presence of 16.6 molecules of lysine per molecule of egg albumin.

Beek[15] studied the quantity of gaseous hydrogen chloride which reacted with collagen and concluded that the number of nitrogen atoms in a unit structure of collagen is 38 or a multiple of 38. He later showed[16] that 3 nitrogen atoms in each unit of 38 are strongly basic. Assuming that the acid bound by collagen is held by the free basic groups of lysine and arginine, and taking the known analyses for the content of these amino acids in collagen, which indicate approximately 2 molecules of arginine to one of lysine, it may be concluded that one of the three basic nitrogens is the ε-amino group of lysine[17]. Calculation of the lysine content from his data then indicates the presence of 4.9 per cent of lysine, which is in good agreement with the value 4.5 per cent shown in table 4.

IV. SUMMARY

An apparatus for determining the rate of evolution of nitrogen from proteins and other amino compounds during treatment with nitrous acid is described. Examination of the rate curves of a number of proteins indicates that there is a primary reaction with a relatively rapid evolution of nitrogen, followed by a secondary reaction with a much slower evolution of nitrogen in which the rate is approximately constant. Extrapolation of the straight line portions of the curves to zero time gives values which appear to be good estimates of the amino nitrogen contents of the proteins. In the case of crystalline egg albumin and collagen, the extrapolated values are in good agreement with values obtained by other methods. No conclusions relative to the significance of the slopes of the curves are drawn at this time.

V. ACKNOWLEDGMENT

The authors express their indebtedness to Martin Shepherd for assistance in designing the apparatus used in this work and for many helpful suggestions relative to its operation.

* Examination of the slopes of the curves indicates that in general, no conclusions can be drawn at this time relative to the relation between the slopes and arginine contents. A rough correlation is evident: for example, silk and zein are low in arginine content and also have the smallest slopes. There is however, evidence which indicates that the slopes may be partially dependent on the physical state of the protein. Further work is in progress.

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Textile Color Terms, Specifications and Problems*

WM. D. APPEL[1]

WHAT words are used in the textile industry to describe colors and color differences? What do these words mean? What specifications relating to color are generally recognized and used in the industry? What are the important textile color problems?

The Committee on Color of the Research Committee, American Association of Textile Chemists and Colorists, undertook to answer these questions at the request of the Inter-Society Color Council of which the Association is a member.

Tentative answers were prepared from the statements of a few dyers and dye chemists and published in the Proceedings of the Association[2] with a request for criticisms and suggestions for improving or adding to them. In addition, letters requesting this help were sent to all members of the Research Committee. The present paper is a summary of the information thus obtained.[3]

The purpose of this survey is to focus attention on the present color nomenclature and problems of the textile industry. It is hoped thereby to stimulate interest in these subjects and to promote a better understanding of them. If there is sufficient interest, it may be possible by concerted effort to develop a generally acceptable uniform system of describing colors and color differences and to solve some of the outstanding color problems. Similar surveys are being made in other organizations concerned with color in industry, in the arts, and in science. A comparison of the results obtained by these groups will be of general interest.

COLOR TERMS

Color terminology has not been formally developed in the textile industry and there is no "official" set of terms. The following terms are rather commonly used in the sense indicated. It should be noted that the textile dyer is concerned not so much with describing colors as such as with comparison of dyeings which should match in color but which may vary slightly, and with describing colors from the standpoint of the dyeing operations. The textile dyer and colorist often means "dye" when he says "color"; however, he also uses the term in the sense defined by Jones,[4] chairman of the O.S.A. Colorimetry Committee: "Color is the general name for the non-spatial component of the sensation arising from the activity of the retina of the eye and its associated nerve systems."

Barre, Barry—Having bars or streaks across the fabric, that is in the direction of the filling yarns.

Bleach—To make whiter.

Bleed—A color is said to bleed when some of the coloring matter passes from the fabric into a liquid, usually water, in contact with it. It bleeds into another fabric when the coloring matter is transferred to the second, usually white, fabric, through the action of a solvent.

Bloom, Bloomy—Bright and rich in color when viewed overhand (which see).

Blotchy—Having relatively large (over 1 inch in diameter) irregular patches of a color somewhat different from that of the rest of the fabric.

Blurry—Having uncertain, that is, not clear, outlines.

* Publication approved by the Director of the National Bureau of Standards, U. S. Department of Commerce, and by A.A.T.C.C. Committee on Color, Walter M. Scott, Chairman.

[1] Member, Committee on Color, Research Committee, A.A.T.C.C.; Chief, Textile Section, National Bureau of Standards.

[2] "Textile Color Terms, Specifications and Problems" American Dyestuff Reporter *26*, pp. P105-P107, (Feb. 22, 1937).

[3] The members of the Association whose names follow have contributed helpful information about the practices in the industry: K. H. Barnard, J. Robert Bonnar, Hugh Christison, J. N. Dalton, Walter C. Durfee, B. L. Hathorne. Henry Herrmann, George H. Johnson, Harold B. Leitch, A. R. Thompson Jr., Chas. B. Ordway, W. S. Williams.

[4] Colorimetry: Preliminary draft of a report on nomenclature and definitions. Loyd A. Jones. Jour. Optical Soc. of America *27*, 207-213 (June 1937).

Bright—Brilliant, vivid, lively in appearance, opposite of dull.

Brightness—The brightness of a color is its vividness, usually relative to some other similar color with which it is being compared. Opposite of dullness.

Bronzy—Having a metallic surface appearance that partly obscures the body color of the material. Bronziness is usually yellowish, greenish, or reddish and complementary to the body color.

Cast—Tendency toward, as "green cast", "red cast".

Clean, clear—Free from a tendency to be dull, dingy, gray, dusty or cloudy in appearance.

Cloudy—Blotchy, uneven color.

Crock—In some localities a color is said to crock when the dye rubs off. In other localities a color is said to crock if it will bleed when wet. The words "rub" and "bleed" and their derivatives should be used instead of crock to avoid misunderstandings.

Dark—Having the appearance of reflecting only a limited amount of light, tending toward black, opposite of light.

Dingy—Having a dull appearance.

Downhand—Viewed with the line of vision approximately perpendicular to the surface.

Dull—(1) Opposite of bright or vivid; (2) cloudy.

Dullness—Opposite of brightness.

Dusty, Dust-tone—Having the appearance of being uniformly covered with dust.

Even—Uniformly colored over the surface.

Fast—Will not fade or change in color on exposure to some named or implied agency, such as light or laundering. Opposite of fugitive.

Flat—Having the appearance of a non-lustrous, diffusely reflecting or matte surface.

Fugitive—Will fade or change color from relatively short exposure to some named or implied agency, such as light or laundering. Opposite of fast.

Full shade—Further additions of the dye will not change the color materially.

Gray—One of the series of colors between black and white, which have little or no hue, i.e., are not reddish, yellowish, greenish, bluish, etc.

Grey—(1) The older English spelling of gray (2) cloth as it comes from the loom or knitting machine before it is subjected to wet processing is sometimes said to be "grey" or "in the gray" condition. Sometimes called "greige" when applied to silk. Wool cloth in this condition is also termed "in the grease".

Heavy Shade—Full shade, opposite of light shade.

Hungry—Lacking in strength and possibly brightness compared with some real or implied standard.

Jet—A black resembling the color of black velvet, which is free from bronze and any tendency toward reddish, greenish or other hue.

Light—Having the appearance of reflecting much light, opposite of dark.

Light Shade—The color resulting from the use of a relatively small amount of dye. Opposite of heavy shade.

Luster—The appearance of a surface which results from its power to exhibit mirror-like reflection.

Masstone—The color a pigment exhibits in its full strength when mixed only with a vehicle, such as a gum solution, oil, or varnish, and viewed in a thick layer.

Mealy—Finely blotched, mottled.

Medium Shade—Intermediate between light shade and heavy shade.

Mode Shade—A color which is fashionable for a certain season.

Mottled—Unevenly colored; variegated; mealy; spotted.

Off-shade—A color which does not match the standard.

Overhand—Viewed when held toward the light and with the line of vision at an acute angle to the surface.

Pastel Shade—Light shade.

Resist—A spot or portion of fabric showing less affinity for dye.

Shade—(1) Same as "color", as: "dyed shade"; "printed shade"; often used to designate a color not greatly different from some particular color under discussion, as a lighter, yellower, or more vivid shade. (2) Shade is a term expressing any variation in color not attributable to variation in strength of dyeing. The "shade" of a green is commonly described as yellow or blue, light or dark, bright or dull; of a red as yellow or blue, etc.; of a yellow as green or red, etc. Sometimes "shade" relates only to hue or spectral character. Sometimes it relates also to brightness. The "shade" of a dyeing is the shade of its color and the "shade" of a dye is the shade of the color of dyeings made with it.

Shaded—Showing a gradation in color, for example from selvage to selvage, or selvage to center of a piece.

Solid Color—Uniform color.

Specky—Showing specks or small particles of matter of a different color from the rest of the fabric.

Spotty—Non-uniform over small areas, mottled.

Streaks, Streaky—Dark or light marks running lengthwise (warp-wise) of a fabric.

Strength—The strength of a dyeing is the amount of dye introduced in the dye bath to dye a given amount of material, usually expressed as a percentage of the weight of the material. See strong.

Strong—A comparative term used to indicate that one dyeing has the appearance of having been dyed with more dye than the other. Opposite of weak. One dye is said to be stronger or to have greater strength than another if a given weight of it will dye more material to the given color than the same weight of the other dye.

Thin—Weak, hungry.

Tinctorial Power—The effectiveness of a given weight of dye in dyeing a given weight of material.

Tone—Hue or spectral character of a color, sometimes "color".

Two-sided—The two sides of the fabric are different in color.

Undertone—The color a pigment exhibits when mixed with a vehicle, such as a gum solution, oil, or varnish, and spread thinly on white paper or when diluted with a considerable amount of white pigment.

Vivid—Bright.

Weak—The opposite of strong.

White—Any one of a range of colors having an appearance similar to that of a perfectly reflecting, perfectly diffusing surface.

Whiteness—The degree of approach to the appearance of the perfectly reflecting, perfectly diffusing surface.

COLOR SPECIFICATIONS

The colors of textiles are generally specified in general non-technical terms or else by reference to a standard sample of material of the desired color. The color cards of the Textile Color Card Association of the U.S.A. Inc., are commonly used as a basis of reference.

Federal Specification TT-C-591 "Colors; (for) American Flag" is applicable to bunting purchased by the Federal Government. This specification requires that the colors shall match the colors of standard samples when inspected under carefully prescribed conditions. The colors of the standard samples are recorded in terms of trichromatic coefficients (I.C.I. System) derived from spectrophotometric measurements.

Federal Specification T-R-601 for "Rope; Manila" includes requirements for the "Becker" value or "per cent reflection of the fiber samples, prepared, and measured under" carefully prescribed conditions.

The fastness of the color of a textile or ability of the textile to withstand external agencies and not to fade is specified by means of fastness tests. Standard fastness tests are provided in the 1935-6 Year Book of the American Association of Textile Chemists and Colorists. Standard dyed cotton, wool and silk fabrics representing the different degrees of fastness to washing have been prepared by this association for sale at a nominal price. The kinds of fastness covered and the language used in some of the tests to specify or describe color changes are given briefly below.

Fastness tests for dyed or printed cotton:

To laundering and domestic washing; "samples that stand test No. — without material alteration in shade or staining of white cloth are considered fast . . ."

To fulling; "shade unaltered"; "shade not altered or only slightly so."

Fastness to chlorine; "color shows a distinct loss in strength or change in shade"; "color shows no loss in strength or change in shade".

Fastness to stoving; "shade changed considerably"; "shades lightly changed."

Fastness tests for dyed or printed rayon:

To laundering and domestic washing.

Fastness tests for dyed or printed silk:

To washing of dyestuffs on silk: "note alteration in color and staining of . . ."; "no greater alteration in color than the standard for this class in tests Nos. . . . " Laundering or domestic washing; "no appreciable alteration . . ."

To fulling; "colors in this group show a noticeable alteration," "very slight alteration", "without noticeable alteration."

To degumming of dyed silk; "greater alteration in color than the standard."

To stoving of dyed silk; "depth and shade changed", ". . . slightly changed", "not changed".

To peroxide bleaching of dyed silk; "no appreciable alteration in color".

Fastness tests for dyed wool:

To laundering and domestic washing of dyed woolen material; "dyeings of these colors . . . show an appreciable change"; "no greater change than . . . ", "practically no change".

To fulling, scouring and mill washing.

To dry and wet heat; "shade changes and does not return to original", "shade changes but returns to original", "no change in shade".

To stoving: "shade changed considerably", "shade changed only slightly".

Fastness to perspiration.

Fastness to light.

Fastness to acids and alkalies; "change in shade is noted", "not altered", "slightly altered", "distinct alteration".

Fastness to carbonizing.

Fastness to sea water.

Fastness to crocking.

The American Society for Testing Materials has tentative standard methods for:

Fastness of dyed or printed cotton fabrics to laundering or domestic washing, A.S.T.M. designation D435-36T.

"The color of the test specimen shall be compared by eye with the color of the corresponding unwashed specimen. In making the comparison, the specimens shall always be held parallel to each other and viewed at the same angle under a standard daylight lamp or equivalent illumination." "The fastness of the specimen shall be determined by a comparison with the fastness of a standard dyeing tested in the same way and at the same time."

Fastness of dyed or printed silk or rayon fabrics to laundering or domestic washing, A.S.T.M. designation D436-36T.

Commercial Standard CS-59-36 "Woven dress fabrics. Testing and Reporting" provides standard methods of testing and reporting color fastness to crocking (rubbing), cleaning (dry and wet), dry pressing, laundering and light.

"The color of the . . . specimen is compared with that of the original fabric. . . ." "The color fastness may be determined by a visual comparison with the fastness of the standard dyeings tested in the same way and preferably simultaneously." "The color fastness of a fabric shall be reported as 'comparable to standard sample. . . .'".

Federal Specification CCC-T-191 for "Textiles; test methods" contains the general methods of test applicable to Government purchases of textiles. Tests are given for color fastness to light; weather; laundering (washing) for materials containing wool, silk, or rayon; water; salt water and soap; crocking; perspiration.

"When no standard sample has been established, the tested specimen shall be compared with the original material and rated on the following basis:

"Good: No appreciable alteration of color.

"Fair: Appreciable but not objectionable alteration of color.

"Poor: Objectionable alteration of color.

"The judgment of the inspector may be aided by comparison with the material from former satisfactory purchases if these are available. Such material should be tested at the same time and in the same way as the material to be graded.

"When a standard sample has been established, specimens from the material to be graded and from the standard shall be tested simultaneously and in the same way and rated in fastness on the following basis:

"Satisfactory: Equal or superior to the standard in fastness.

"Unsatisfactory: Inferior to the standard in fastness."

COLOR PROBLEMS

The textile industry is concerned with dyes, their evaluation for use on textiles, the dyeing and printing of textiles to obtain given color effects, the properties of the dyed and printed products in storage, use, laundering, and cleaning. A long list of important problems relating to the production and use of textiles whose appearance and color depends upon bleaching, dyeing, printing, lustering, delustering, and similar treatments could be given. Insofar as these *dye* and *textile* problems are concerned with color per se, they involve the problems of: (1) describing color appearances found in textiles, (2) measuring colors accurately and yet rapidly, (3) evaluating differences between similar colors and changes in colors, (4) evaluating whiteness, luster, bronziness, bloom, and the like.

Stress-Strain Characteristics of Wool as Related to its Chemical Constitution

ARNOLD M. SOOKNE and MILTON HARRIS*

An apparatus for studying the extensibility of single wool fibers is described. Data on the effect of the tanning (quinone), dyeing, and deamination processes, and of neutral salts on the extensibility of the wool fibers are reported. The results indicate that the extensibility of the wool fibers is governed, for the most part, by factors which influence the swelling or hydration of the protein. Salt linkages of the type which might be formed by an attraction between the free amino and carboxyl groups in wool do not appreciably contribute to the physical stability of the fiber in aqueous solutions.

I. INTRODUCTION

THE classical view of protein structure, based on the work of Emil Fischer and his contemporaries, is that the protein molecule is a polypeptide composed of a series of amino acids united through their carboxyl and amino groups. These earlier workers focused their attention on the isolation and identification of the protein constituents and obtained large amounts of information which supported this view. Their work was of great importance in protein chemistry, but from the standpoint of protein structure, and more especially, the structure of protein fibers, it proved of limited value until recently, when it was augmented by physical-chemical methods and X-ray studies.

The more recent advances in the X-ray studies of wool and similar materials have been made by Astbury and his collaborators[1] whose investigations indicate that the fiber consists of long-chain molecules (polypeptides) which lie parallel to the fiber axis and which are held together by a variety of cross-linkages of the covalent and electrovalent types. That most of the covalent cross-linkages in wool are those of the disulfide groups of the amino acid, cystine, is at the present time generally accepted. On the other hand, little is known about the nature of the electrovalent forces.

As a result of a number of studies, principally on the changes in the extensibility of wool brought about by various treatments of the fiber, Speakman and Hirst[2] postulated the existence of electrovalent linkages between the free acid groups of the glutamic and aspartic acids and the free basic groups of the arginine, lysine, and histidine constituents of the polypeptides in wool, which they termed salt linkages. Presumably the attractive forces between the oppositely charged $R\text{-}COO^-$ and $R\text{-}NH^+_3$ ions are reduced by water and for this reason the wool fiber is more easily stretched in water than in dry air. Similarly, they postulated that since acids and alkalies would depress the ionization of the free acid and basic groups which make up the salt linkage, they would increase the ease of stretching to an even greater extent.

The presence of salt linkages in various proteins has been suggested by different investigators and there appears to be some evidence for their existence. The question has arisen therefore as to whether salt linkages, formed by the attraction between the free amino and carboxyl groups, contribute appreciably to the physical strength of the wool fibers.

The results of studies on the extensibility of wool fibers are reported here for the purpose of further elucidating the nature of the electrovalent linkages in wool. In addition, some of the data have been applied to an interpretation of the tanning, dyeing, and deamination of wool.

II. DESCRIPTION OF APPARATUS AND METHOD

The stretching of wool under load has been extensively investigated by Harrison[3], Karger and Schmid[4], Shorter[5], Astbury and Woods[6] and especially by Speakman[2, 7]. The general procedure has been to determine the load-elongation curves of fibers under various conditions. This procedure has been followed in the present work. The method employed is relatively simple and requires little equipment that is not generally available.

A sample of domestic wool was purified by successive extractions with alcohol and ether, followed by washing with water at about 40° C. The fibers were for the most part non-medullated and were fairly uniform in width along the 4-cm. length used in this work, the average width as measured at 20 places being about 35 microns. Before measuring the fiber width, each end of the fiber was attached to a platinum-iridium hook, weighing about 0.35 gm., with asphalt (dissolved in chloroform) as the binding material. The measurements of the widths of the fibers were made in a room at 21° C. and 65 per cent relative humidity, using a projection microscope equipped with a heat filter, and giving a magnification of about 700 diameters. Duplicate determinations of the effective diameter

*Research Associates at the National Bureau of Standards representing the A.A.T.C.C. This work was aided by grants from the Textile Foundation, Inc., and the Chemical Foundation, Inc.

of the same fiber checked to within 1 per cent. In addition to this method for the direct determination of fiber width, the fibers were calibrated by a re-extension method, described later in this section.

The fibers were always soaked for 24 hours at 21° C. in the solutions in which they were to be stretched. Loads were applied to the fibers and the extension was measured with the analytical balance and auxiliary equipment shown in Figure 1. A fiber (E) of known length was attached

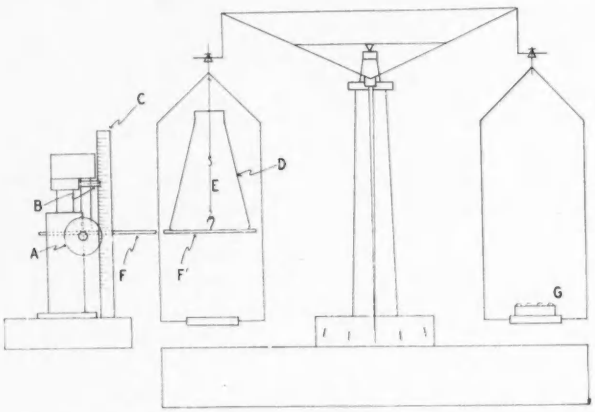

Fig. 1—Apparatus for determining the load-elongation curves of single wool fibers.

to the left side of the balance beam and the pointer of the balance was brought to the zero position by adding weights on the left hand pan to counterbalance the rubber pad G. The lower hook on the fiber was then attached to the glass hook sealed to the bottom of the 250 ml. Erlenmeyer flask (D) resting on the movable platform (F)*. The flask D contained enough of a given solution to assure complete immersion of the fiber during elongation. The load was applied by the addition of steel balls, each weighing 0.4392 ± .0004 g., to a sponge rubber pad on the right-hand balance pan. The rubber pad contained small holes, each of which held one steel ball. The application of this stress causes an elongation of the fiber and a consequent leftward displacement of the pointer of the balance. By lowering the platform (F), using the thumbscrew (A), the pointer was returned to the zero position, and the extent of vertical displacement was read on the scale (C) by the index (B). Elongation was read in this manner to 0.1 mm. The balls were added at 30-second intervals, and readings of elongation were made 15 seconds after the addition of each ball. The rate of applying stress for the fibers studied was approximately 1 x 10^5 g./cm.^{2}/minute. The length at zero load was obtained by extrapolation, correcting for the weight of the lower hook. All load-elongation measurements were made at 21° C.

The method described above has several advantages in addition to its simplicity. The regular lowering of the platform maintains the fiber in an effectively vertical position, which assures application of the full apparent stress. The platform may be allowed to remain in position long enough to make an unhurried reading of the scale. Although the loading process is a discontinuous one, which at first sight appears to be a disadvantage, the reproducibility of the measurements and the sensitivity of the method show this type of loading to be satisfactory for the determination of the load-elongation curves.

A typical load-elongation curve obtained with this apparatus for an untreated wool fiber in equilibrium with water at 21° C. is shown in Figure 2 (curve 1). Speak-

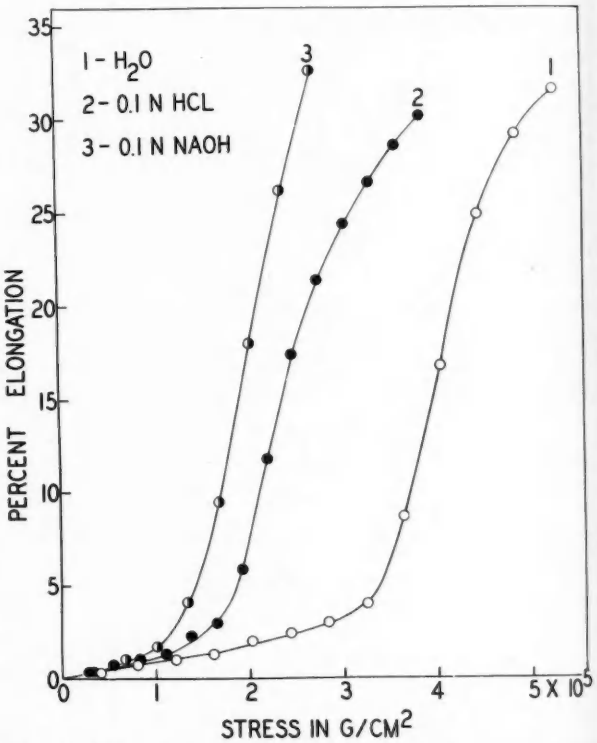

Fig. 2—Stress-strain load-elongation curves for wool fibers immersed in water, and in acid and alkaline solutions.

man[7] has shown that such curves are most reproducible up to an elongation of 30 per cent and that the area to the left of the curve, representing the amount of energy necessary to produce a given elongation, is a sensitive measure of changes in fiber extensibility. When the fibers are stretched beyond 30 per cent, permanent alterations in their extensibility may occur.

As shown in curves 2 and 3 of Figure 2, the load-elongation curves vary with different treatments of the fiber. The smaller areas to the left of the curves obtained in the hydrochloric acid and sodium hydroxide solutions show that less energy is required to stretch the fibers 30 per cent in these media.

Since all measurements were made in aqueous solutions, the amount of energy necessary to elongate a fiber 30 per cent in distilled water (approximately pH 5.8) was taken

*During operation, platform F is in position F'.

as a standard. Comparison of the extensibilities of fibers in various solutions was facilitated by calculating the "30 per cent index," which is defined as the ratio of the energy required to elongate a treated or untreated fiber 30 per cent in a given medium to the energy which would be required to elongate the untreated fiber 30 per cent in distilled water. Comparison of data by this method was limited to experiments in which the general shape of the curves was similar to that for an untreated fiber in distilled water.

It has been shown by Speakman[6] that fibers elongated 30 per cent or less, after a 24-hour period of rest without load, will give load-elongation curves very nearly identical with the original curves. That the fibers used in this investigation possess this ability was demonstrated by re-extending in distilled water, five individual fibers which had 24 hours previously been elongated 30 per cent in distilled water. The mean value of their 30 per cent indices was 0.996. Wherever possible, the fibers used in the present work were first extended 30 per cent in distilled water and then allowed to rest without load for 24 hours. They were then re-extended or subjected to some treatment and re-extended in a given medium. This procedure eliminated the necessity of measuring the cross-sectional area used to calculate the energies to a unit cross-sectional area. Fibers to be re-extended by this method are referred to as "calibrated" fibers in this paper.

III. RESULTS AND DISCUSSION

1. Effect of Tanning

Much has been written about tanning and there are many different views as to the nature of tanning processes. However, it is generally accepted that the principal effect of tanning is to decrease the swelling of proteins in aqueous media. In tanning collagen to prepare leather, it has been shown[8] that the acid-combining capacity is appreciably reduced. Tanning appears to affect wool similarly. Wool fibers were treated (refluxed) for 3 days at 50° C. with a saturated solution of quinone in about 50 per cent alcohol, after which they were washed for 24 hours in running distilled water. The quinone-tanned wool had an acid-combining capacity of 0.39 millimole per gram for the untreated fibers, which indicates that approximately half of the basic groups in wool reacted with the quinone.

Determinations of the 30 per cent indices of untreated and quinone-tanned fibers in solutions having pH values ranging from about 1 to 12 are shown in Figure 3. The curve for the untreated wool is similar to that obtained by Speakman and Hirst, which exhibits a region of maximum stability between about pH 5 and 7, a region of linear decrease in the 30 per cent indices from pH 5 to 1 and a region above about pH 10 in which the 30 per cent index decreases rapidly with increasing pH. The maximum region is somewhat smaller than that obtained by Speakman and Hirst in unbuffered solutions but very similar to that obtained by them using acids and alkalies in 0.2 N solutions of sodium chloride. Buffer solutions, prepared according to Clark[9] were used in the present work, which probably accounts for the similarity of the shape of the curve obtained in the present work with that obtained in the presence of dilute solutions of sodium chloride.

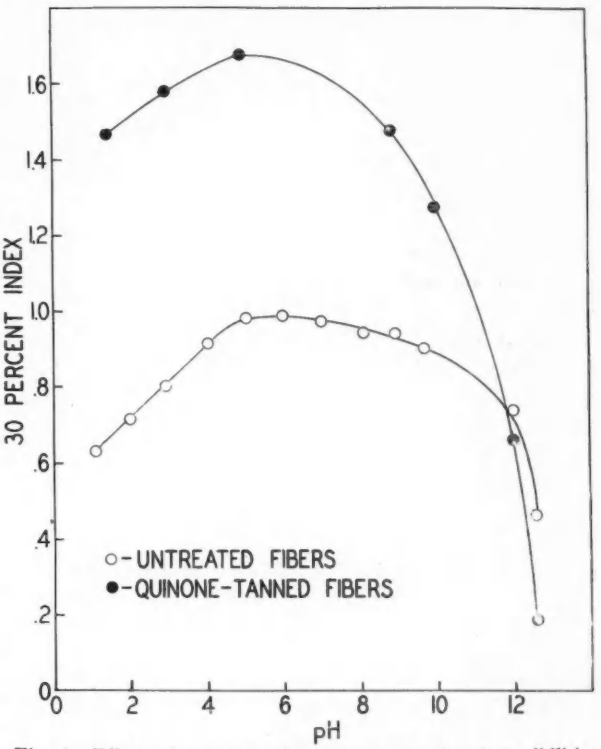

Fig. 3—Effect of tanning with quinone on the extensibilities of wool fibers in solutions of different pH.

The decrease in the 30 per cent index of untreated wool in the acid solutions is practically reversible, since re-extension of the fibers in distilled water after thorough washing yielded 30 per cent indices of more than 0.98. Above pH 8, however, the degree of recovery of the fibers decreases with increasing pH. The 30 per cent index of fibers extended in 0.1 N sodium hydroxide, washed, and re-extended in distilled water was only 0.59. This is in agreement with the known susceptibility of the fibers to chemical degradation in the more alkaline solutions.

It is apparent from the upper curve in Figure 3 that tanning with quinone* decreases the ease of extension of the fibers. The 30 per cent indices were roughly doubled in the acid and neutral solutions although at very high pH values they were lower than those for untreated fibers.

In view of the fact that the tanning process has blocked many of the basic groups in wool (as evidenced by the decreased acid-combining capacity) it would be expected from the salt-linkage theory that less energy would be required to elongate the tanned fibers 30 per cent than is required for untreated fibers. Obviously, this is not so. It appears that the predominant factor affecting the ex-

*As indicated by alkali-solubility determinations no significant amount of oxidation has occurred during treatment with quinone.

tensibility may be the swelling or hydration of the fibers, as will be shown later. For the purpose of explaining the data obtained in the present work, three types of swelling are considered: namely, imbibitional swelling resulting from the absorption of distilled water by wool to form solvates or adsorption compounds; osmotic swelling, in acid or alkaline solutions resulting from the formation of ionizable protein salts; and swelling in solutions of neutral salts, resulting from the effect of the salts on the cohesional and adhesional forces of the water and the protein.

Against the swelling theory, it may be argued that tanned fibers are less readily elongated because of the introduction of large molecules such as quinone into the wool fibers produces new cross-linkages. However, there is no evidence in support of such a theory and furthermore the theory would not account for the low 30 per cent indices in alkaline solutions. Although the affinity of wool for quinone at pH 12 or 13 is not known, the maximum absorption of quinone takes place in alkaline solutions at about pH 8 to 11[10], and it hardly seems probable that at slightly higher pH values the wool would lose all of its affinity for the quinone. A more probable mechanism for the behavior of the tanned fibers is that, in acid solution, less acid is bound by the tanned fibers than by untreated fibers and there is accordingly less osmotic swelling, whereas in alkaline solution, the carboxyl groups, which presumably are unaffected by the quinone, are capable of binding as much alkali as untreated fibers. Thus the normal swelling would take place in alkaline solution in addition to the chemical degradation which is known to occur under these conditions.

It is interesting to note that the decrease in 30 per cent index for the tanned fibers from pH 5 to about pH 1 is about half that for the untreated fibers between the same pH values. The fact that the tanned wool used for these experiments had only about one-half of the acid-combining capacity of the untreated wool is evidence that the extensibility of the fibers in this pH region is proportional to the amount of acid combined, as previously noted by Speakman and Stott[11]. This immediately suggests that at least two effects result from the tanning of wool with quinone; namely, the reaction of a portion of the basic groups with the quinone, which decreases the acid-combining capacity, thus decreasing the Donnan effect (osmotic swelling) in acid solutions, and the reaction of wool with quinone in a manner which decreases the swelling that occurs in water alone (imbibitional swelling), as indicated by the difference in 30 per cent indices of the untreated and tanned fibers in the neutral region. This is also in keeping with the fact that wool takes up much more quinone than is accounted for by the basic groups.

2. Effect of Dyeing with Acid Dyes

The dyeing of wool with a simple acid dye such as Orange II appears to involve a less complicated mechanism than the tanning process. Whereas wool absorbs more quinone than can be accounted for by the basic groups, it has been shown by Smith and Harris[12] that it absorbs only one molecule of acid dye for each basic group when the dyeing is carried to equilibrium. The dyeing appears to be the result of the interaction of the acid groups of the dye molecules with the basic groups in wool, but the nature of the wool-dye compound is not known. If the dyeing results in the formation of highly ionized compounds, it would be expected that the extensibilities of the dyed fibers, for example, at pH 1, would be approximately the same as those of untreated fibers at the same pH. On the other hand, the formation of non-ionized or weakly ionized compounds would appreciably change the extensibilities in acid solution by decreasing that portion of the osmotic swelling caused by the acid. It seemed, therefore, that a study of the extensibilities of completely dyed fibers* would offer some information as to the nature of the wool-acid dye complex in addition to further elucidating the factors which affect the extensibility of the fibers.

Single fibers were calibrated by the re-extension method, then dyed for 20 hours at 50° C. in a solution of Orange II in 0.1 N hydrochloric acid. (The stock solution contained 5 millimoles of dye per liter and sufficient solution was used to assure an excess of dye. It has been shown[12] that under these conditions, wool absorbs about 0.8 millimole of dye per gram.) The fibers were washed in running distilled water for one hour and then allowed to remain in buffer solutions for 24 hours, after which they were re-extended. The results given in Table 1 show that

TABLE 1

A comparison between the 30 per cent indices at different pH values of untreated wool fibers and fibers dyed to equilibrium with Orange II, when extended in buffer solutions of different pH values.

	30 Per Cent Index	
pH	*Dyed Fibers*	*Untreated Fibers*
1.42	1.01	.66
2.98	1.01	.81
4.95	.99	.98
6.90	.88	.99

the extensibilities of the completely dyed fibers in acid solutions are very similar to those of untreated fibers in distilled water. The basic groups not only appear to be blocked by the dye molecules, but they are at the same time rendered practically inactive. In other words, when untreated wool is put in acid solutions, heteropolar compounds of wool and acid are formed which facilitate extension of the fibers (by increasing osmotic swelling) whereas when completely dyed, the wool and dye appear to form compounds which approach homopolar compounds in their behavior.

*Fibers dyed under such conditions that all of the basic groups have reacted with dye molecules[12].

Unfortunately, the 30 per cent indices of the dyed fibers could not be determined in alkaline solutions because of the reversal of the dyeing process. The somewhat low 30 per cent index for the dyed fibers in solutions at pH 6.9 indicates a shift in stability to the more acid region.

3. Effect of Deamination*

It would appear on first sight that the influence of the basic groups on the extensibility of wool could best be studied by comparing the properties of untreated and deaminated fibers. This would have the obvious advantage of eliminating the introduction into wool of new molecules, such as occurs in the tanning and dyeing processes. As will be shown later, however, the action of nitrous acid on wool is not limited to the amino groups and as a result the value of this method of attack is somewhat questionable.

The deamination process has been frequently used by various investigators for the purpose of studying the role of the amino groups in wool. An investigation of the effect of nitrous acid on wool revealed two principal weaknesses in this method; namely, that it is impossible to completely deaminate wool in a reasonable length of time, and that the state of the sulfur of the cystine in wool is altered during deamination.

It has been shown[13, 14] that deaminated proteins retain a considerable portion of their acid-combining capacities, even after prolonged treatment with nitrous acid. Experimental results indicate that there is a sudden drop in acid-combining capacity after a very short treatment with nitrous acid, followed by a very slow decrease in the acid-combining capacities during the continued treatment. This is in agreement with the results of Rutherford, Harris, and Smith[15] who studied the rates of evolution of nitrogen from various proteins during treatment with nitrous acid and found that there is a primary reaction with a rapid rate of evolution of nitrogen, followed by a secondary reaction with a very much slower evolution of nitrogen.

The effect of the deamination process on the state of the sulfur in wool practically precludes the making of rigorous comparisons between the untreated and deaminated fibers. Harris and Smith[16] have recently shown that during treatment with oxidizing agents, the disulfide sulfur appears to be changed to higher states of oxidation, the existence of oxidation derivatives being indicated by four different methods. Nitrous acid is an active oxidizing agent and as such, should also be capable of at least partial oxidation of the sulfur in wool. That oxidation does occur during deamination is indicated by three† of the methods used by Harris and Smith. The deaminated wool gave a negative lead acetate test**, and showed increasing alkali-solubilities and decreasing cystine contents with increasing time of deamination.

In view of these apparent difficulties, it was necessary to reinvestigate the extensibility of deaminated fibers from the standpoint of the different reactions which may occur during deamination. Wool fibers were treated for different lengths of time at 20° C. with a solution of nitrous acid (one volume of glacial acetic acid to four volumes of a solution containing 30 gm. of sodium nitrite in 100 ml. of water), the ratio of solution to wool being approximately 500 to 1. The fibers were thoroughly washed in running distilled water and their 30 per cent indices in solutions of different pH values determined. The results are recorded in Table 2.

TABLE 2

The 30 per cent indices of wool fibers which have been deaminated for different lengths of time with nitrous acid.

Duration of Treatment with HNO_2	*30 Per Cent Indices*			
	pH 1.1	pH 4.0	pH 7.0	pH 12.0
Hours				
0	.66	.93	.98	.76
3	.72	.85	.75	.48
24	.73	.85	.73	.39
48	.74	.84	.68	.29
96	.74	.84	.64	.28
192	.72	.80	.62	.21

From the foregoing discussion on the reactions of wool with nitrous acid, at least two effects of the deamination process on the extensibility of wool fibers may be expected; namely, an increase in 30 per cent index in acid solutions caused by a reduction in osmotic swelling resulting from loss of amino groups and corresponding loss of acid-binding capacity; and a decrease in 30 per cent index caused by oxidation of the disulfide groups and the subsequent weakening of the bonds between the disulfide sulfur atoms. The latter effect should increase with increasing pH, since it has been shown by Lavine[17] and Toennies[18] that the stability of the intermediate oxidation derivatives of cystine decreases with increasing pH.

An examination of the data in Table 2 shows that the results of these experiments are in agreement with the above-mentioned postulates. The 30 per cent indices of all of the deaminated fibers are greater at pH 1.1 than are those of the untreated fibers. At this pH, the inhibition of osmotic swelling resulting from loss of amino groups (the acid-combining capacity of the deaminated fibers is roughly half of that for untreated fibers) is the predominant factor, the partially oxidized disulfide groups being moderately stable at this pH. At pH 4 the 30 per cent indices are slightly lower than for the untreated fibers. Since the number of basic groups in the deaminated wool is far greater than the number of moles of acid bound by wool at pH 4, it is to be expected that

*In the present paper, deamination refers only to removal of amino groups with nitrous acid and has no quantitative significance as to the extent of completeness of their removal.

†The fourth method, namely, reduction with hydrochloric acid-potassium iodide solutions, could not be used because of interference from what appeared to be nitroso derivatives formed during deamination.

**Samples of wool were prepared for this test by deamination at 0-5° C. to prevent excessive yellowing of the wool.

there should be very little difference between the osmotic swelling of the treated and untreated fibers. However, at this pH the instability of the oxidized sulfur groups becomes appreciable[17], thus accounting for the lowering of the 30 per cent indices of the deaminated fibers. At the higher pH values, the differences become ever more pronounced since the instability of the oxidized sulfur groups increases rapidly in alkaline solutions. The effects of the prolonged treatments with nitrous acid are especially noticeable at pH 7 and above. Fibers deaminated for 48 hours or longer and stretched in solutions at pH 12, no longer gave load-elongation curves similar to those for untreated fibers.

According to Speakman and Stott[13], "the resistance of wool fibers to extension is less in acid solution than in water, owing to the rupture of salt linkages between peptide chains. Similarly, deaminated fibers are less resistant to extension in water than untreated fibers, the reduction in the resistance to extension being dependent on the extent of deamination.—*A critical test for complete deamination is to be found in the fact that completely deaminated fibers should be no more difficult to stretch in water than in hydrochloric acid solution at pH 1.*" (Italics ours.) In addition, Speakman and Stott presented data which presumably indicated that the load-extension curve of completely deaminated fibers in distilled water and at pH 1 are almost identical.

The results of the present investigation show that the extensibilities of deaminated fibers cannot be used as a measure of the completeness of deamination. Deaminated fibers were found to be more resistant to extension in a solution of pH 1.1 than untreated fibers in spite of the apparent attack on the sulfur groups, which indicates that the main effect at this pH is the lowering of the osmotic swelling by reducing the amount of acid bound by the wool. The ease of extension of the deaminated fibers in neutral solution (pH 7.0) increases relatively rapidly with increasing duration of deamination, whereas at pH 1.1 the fibers at first become slightly more difficult and then slightly easier to stretch. In other words, the extensibilities of deaminated fibers in solutions of pH 1 and pH 7 are not the same nor are the changes which are produced in the ease of extension in the two solutions, the result of the same reaction. It follows then that complete deamination cannot be defined in terms of the extensibility of wool. It appears that Speakman and Stott's[13] conclusion that wool fibers may be "completely deaminated" by 50 hours' treatment with the Van Slyke reagent was the result of a coincidence in which they obtained practically identical load-elongation curves for a deaminated fiber in distilled water and at pH 1. As was previously pointed out, the 30 per cent indices for deaminated fibers at pH 1.1 are almost constant, while those obtained at pH 7 decrease with increasing duration of treatment with nitrous acid. It should be noted that extending strongly deaminated fibers more than once is a questionable procedure and as a result at least three fibers, previously calibrated and then deaminated, were used for each determination shown in Table 2.

4. Effect of Neutral Salts

In addition to the effect produced by acids and alkalies, neutral salts also may have a marked influence on the swelling of wool. Actually there are salts which depress swelling as well as salts which increase it, the former producing what is commonly known as "salting out" and the latter, "salting in" or "peptization." The relative effect of various salts was first investigated by Hofmeister[19] who arranged the salts in an order corresponding to their effects on the proteins.

Whereas an insoluble protein such as wool may swell in distilled water by an imbibition process and in acids or alkalies by osmotic forces resulting from salt formation, the mechanism by which salts influence the swelling has not been satisfactorily explained. It appears, as suggested by Gibson and Kincaid[20] that the salts influence the structure of water by strengthening or weakening the electrostatic bonds which hold the molecules of water together. There is also the possibility that the salts influence the forces of cohesion in the protein. It would be expected, then, that when the cohesional forces between the water molecules becomes relatively greater than the adhesional forces between the protein and water, depression of swelling ("salting-out") will take place. Similarly, when the adhesional forces between water and protein are relatively greater, increased swelling ("salting-in") will result.

Since the pH of solutions of most of the neutral salts lie within the pH stability range for wool, and since the free amino and carboxyl groups should not be attacked by the salts, the investigation of the effect of various neutral salts offered another approach to the study of the nature of the forces involved in the extension of the fibers. Accordingly, calibrated fibers were soaked for 24 hours in 1 N solutions of various potassium salts and then extended in the same solutions. When the data was arranged in order of decreasing 30 per cent indices as shown in Table 3, it was found that the anions of the salts were arranged

TABLE 3

The effect of normal solutions of various potassium salts on the extensibility of wool fibers.

Solution	30 *Per Cent Index*
1 N K_2SO_4	1.03
1 N $KOOCCH_3$	1.02
1 N KCl	1.01
1 N KBr	.97
1 N KI	.90
1 N KCNS	.83

in an order corresponding to their ability to increase the swelling of proteins[19].

That the salts influenced the swelling of the wool fibers was corroborated by measuring the change in the diam-

eters of fibers immersed in 1 N solutions of potassium bromide and potassium thiocyanate. The method employed was similar to that described by Speakman and Stott[11] and consisted essentially in the mounting of 5 fibers on a glass slide marked with 10 lines, 1 mm. apart so that the fibers and lines crossed each other at right angles. The ends of the fibers were sealed to the glass with asphalt so that the slide and fibers could be immersed in any liquid under consideration. The fiber widths were determined microscopically on both sides of the intersections of the fibers and the lines, so that 100 measurements were made on each slide. All the experiments were conducted in a room kept at 21° C. The widths were first determined after soaking in distilled water for 24 hours and then after 24 hours in the desired reagent. By this method, it was found that the average widths of the wool fiber increased 0.2 per cent in 1 N potassium bromide, and 1.0 per cent in 1 N potassium thiocyanate solutions over what they were in distilled water.

Speakman and Hirst[2] investigated the stretching of wool in 0.2 N solutions of sodium chloride containing varying amounts of hydrochloric acid, with the idea of studying the action of acids on wool in the absence of swelling. From their results they concluded that "the fact that swelling can be reduced without interfering with the action of acid in facilitating fiber-extension, is a confirmation of the view that swelling is not the primary cause of a reduced resistance to extension." However, actual measurements of fiber diameters indicate that in 0.1 N hydrochloric acid solutions the amount of sodium chloride they used reduces the swelling obtained with acid alone by only about 25 per cent. If, however, a 0.1 N solution of hydrochloric acid saturated with sodium chloride is used, not only does the osmotic swelling produced by the acid appear to be eliminated but there also appears to be a contraction in fiber width. Consistent with this is the fact that wool fibers are more difficult to elongate in such a solution than in water, the 30 per cent index for the fibers being 1.10. The acid-combining capacity of wool in a 0.1 N solution of hydrochloric acid, saturated with sodium chloride is 1.12* millimoles of acid per gram of wool, which indicates that any existing salt linkages would have ben broken and on the basis of the salt-linkage theory, the fiber should have been easier to stretch.

IV. THE RELATION OF SWELLING TO THE EXTENSIBILITY OF WOOL

Although it has been shown that the extensibility of a fiber is qualitatively influenced by the factors which affect the swelling of the wool, it is not to be expected that the ease of elongation will be directly proportional to the degree of swelling. That there is a relationship for a specific type of swelling is shown in Table 3 and in Figure 4. The

*This is not strictly comparable to the value of 0.80 obtained for 0.1 N HCl alone, in which no correction is made for swelling. Reduction of swelling by the NaCl gives a higher apparent value for the acid-combining capacity. In addition, the hydrogen ion activity of the solutions is greatly changed by the NaCl[21].

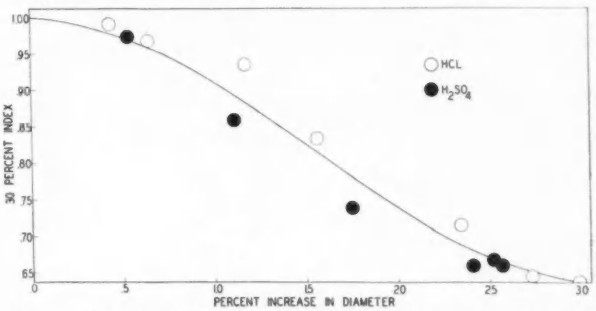

Fig. 4—Relation between extensibility and swelling of wool fibers in acid solutions of different concentrations. Data from Speakman[2, 11]

data for the latter are those of Speakman[2, 11] and his collaborators. The curve indicates a relationship between the ease of elongation and the osmotic swelling. However, when the effects of osmotic swelling and swelling produced by a "salting-in" salt on the extensibilities of the fibers are compared, somewhat different results are obtained. The 30 per cent indices of fibers stretched in a hydrochloric acid solution of pH 2.9 and in a 5 N solution of lithium bromide are 0.81 and 0.82 respectively. The average increase in the fiber diameter in the acid solution as compared to water was 1.8 per cent and in the lithium bromide solution, 3.1 per cent. A possible explanation for such differences may be found in a consideration of the electrovalent linkages in the wool molecule. As was previously pointed out, the fiber appears to consist of long-chain polypeptides held together by a variety of cross-linkages of the covalent and electrovalent types. The valence forces vary according to the type of linkage. The electrovalent forces, however, are of essentially two types; Coulomb forces which vary inversely as the square of the distance and Van der Waal's forces which vary inversely as the sixth and higher powers of the distance. It is obvious then that the extensibility of the fiber should depend on the relative properties of the various types of forces which are affected in the different types of swelling. In other words, a given amount of swelling which involves a relatively high proportion of Coulomb forces should produce a less extensible fiber than a similar amount of swelling involving a higher proportion of Van der Waal's forces.

V. SUMMARY

The results of this investigation indicate that salt linkages of the type which might be formed by an attraction between the free amino and carboxyl groups in wool do not appreciably contribute to the physical stability of the fiber in aqueous solutions. It appears that the extensibility of wool fibers in aqueous solutions is governed, for the most part, by factors which influence the swelling or hydration of the wool. For the purpose of explaining the data obtained in the present work, three types of swelling are considered; namely, imbibitional swelling resulting from the absorption of distilled water by wool to form solvents or adsorption compounds; osmtic swelling, in acid or alkaline solutions resulting from the formation of ioniz-

able protein salts; and swelling in solutions of neutral salts, resulting from the effect of the salts on the cohesional and adhesional forces of the water and the protein.

Tanning with quinone appears to decrease the ease of extension of the fibers (except in strongly alkaline solutions) by decreasing the swelling of the wool. The experimental data suggest that part of the effect results from blocking some of the basic groups and reducing some of the osmotic swelling, while the remainder of the effect is caused by a decrease in imbibitional swelling. The results are consistent with the fact that proteins take up more tanning materials than can be accounted for by the basic groups.

The extensibility of fibers dyed to their maximum capacity with acid dyes, is the same in acid solution as that of untreated fibers in distilled water. It is concluded from these experiments that only the osmotic swelling caused by addition of acids is eliminated. The wool and acid dye appear to combine in stoichiometric proportions to form compounds which approach homopolar compounds in their behavior.

The extensibilities of deaminated fibers are very different from those of the untreated fibers. At pH 1.1, fibers deaminated to different degrees are all less extensible than the untreated fibers. At pH 4 and above, the deaminated fibers are more extensible than the untreated fibers, the ease of elongation increasing with increasing pH and with degree of deamination. An investigation of the effect of nitrous acid on wool revealed that at least two reactions occurred which would affect the extensibility of the fibers; namely, a splitting off of basic groups and an oxidation of disulfide groups. The effect of removing the amino groups, which decreases the amount of acid bound, is most pronounced when the fibers are extended in the strongly acid solutions. The osmotic swelling is decreased and this results in a decreased extensibility. This effect becomes less pronounced as the pH of the solutions with which the wool is in contact increases. On the other hand, the effect on the sulfur is at a minimum in the more acid solutions but becomes more pronounced as the pH increases. The net effect then, is a combination of the two reactions.

Neutral salts increase the ease of elongation of the fibers in an order corresponding to their abilities to increase the swelling of proteins. 0.2 N solutions of sodium chloride cause only a relatively small decrease in the osmotic swelling produced by hydrochloric acid. However, saturated solutions of this salt not only appear to eliminate the osmotic swelling produced by 0.1 N hydrochloric acid but also actually produce a contraction in the fiber. In spite of the fact that in such a system, the wool takes up more acid than wool in acid solutions without sodium chloride, the fibers in contact with the acid-salt solution are more difficult to stretch than untreated fibers in water alone.

Although the extensibility of the fiber is modified by the factors which affect the swelling of wool, it is not necessarily directly proportional to the degree of swelling. In general, it appears to depend on the relative proportion of the different electrovalent cross-linkages which are affected in each type of swelling.

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Evaluation of Crush Resistant Finishing Treatments for Fabrics*

HERBERT F. SCHIEFER†

ABSTRACT

THE results of measurements by the compressometer method of certain compressional characteristics of representative transparent velvet fabrics before and after the application of commercial crush-resistant finishes are reported and discussed. These finishing treatments markedly change the compression and recovery characteristics of the untreated fabric and in general increase the "compressional resilience" of the pile. These changes appear to correlate with the changes in the appearance produced in the fabrics when small areas of the various specimens are compressed with the compressometer.

INTRODUCTORY STATEMENT

Perhaps the most unsatisfactory tests in textile analysis are those for evaluating the "hand or feel" of a fabric. With the increasing interest in permanent and anti-crease finishes, the need of quantitative, scientific methods for measuring these finishes, has become acute.

Dr. Herbert F. Schiefer of the National Bureau of Standards in the following Paper offers a clean-cut, accurate, and scientific method for evaluating one of the physical factors, viz., The Crush Resistance of Pile Fabrics.

Your Sub-committee on this subject takes great pleasure in recommending his work to your attention. We have been promised a similar Paper on: the Testing of Plain Fabrics in the near future.

KENNETH H. BARNARD,
Chairman.

I. INTRODUCTION

The utility of pile fabrics depends, among other things, upon the resistance to crushing or deformation and matting of the yarns and fibers forming the pile. Pile dress fabrics, notably transparent velvets with rayon pile, have been particularly troublesome in this respect. The application to such fabrics of synthetic resins by what are called crush-resistant finishing treatments has resulted in much more serviceable products. The work reported in this paper was undertaken to determine the applicability of the compressometer to the evaluation of crush-resistant treatments on pile dress fabrics.

II. PROCEDURE

Representative transparent velvet fabrics, before and after the application of crush-resistant finishing treatments, were furnished for the work by several manufacturers. Samples of these fabrics were conditioned by exposure for several days in an atmosphere of 65 per cent relative humidity and a temperature of 70° F. and were tested in this condition.

The compressometer, illustrated in figure 1, is described in detail in a previous publication[1]. By turning the knurled knobs, shown in the center of the figure, the circular presser foot, which is one inch in diameter, is lowered and a fabric placed on the anvil below it is compressed. The load applied to the fabric by the foot for any position of the knurled knobs is indicated on the upper dial of the instrument. The thickness of the fabric at that load, that is, the distance from the presser foot to the anvil, is indicated on the lower dial.

The fabric to be tested was subjected to a series of increasing pressures from 0.25 to 5.0 pounds per square inch in increments of 0.25 pound per square inch for pressures up to 1.0 pound per square inch and of 0.5 pound per square inch thereafter, and the thickness at each pressure was observed and recorded. Similar observations were then made for decreasing pressure. The time between observations was about 10 seconds. Each fabric was measured in at least 5 different places and the averages of the values for each pressure were used. It was found necessary to adjust the presser foot parallel to the anvil before starting to measure each new place on pile fabrics.

The results were plotted in the form of curves, showing the compression and recovery of the fabrics. In addition, the energy expended in compressing the fabric as the pressure was increased from 0.25 to 5.0 pounds per square inch and the energy recovered when the pressure was decreased over this range were calculated.* The ratio of the energy of recovery to the energy of compression was taken as a measure of the "compressional resilience" of the fabrics.

III. DISCUSSION OF RESULTS

In a transparent velvet the cut tufts of the pile yarns, which are exposed on one side of the fabric, are bound in

*Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

†Member of A.A.T.C.C. Committee on Test Methods for Crease Resistance and permanent finishes.

[1]Herbert F. Schiefer, The compressometer, an instrument for evaluating the thickness, compressibility, and compressional resilience of textiles and similar materials. BS J. Research *10*, 705 (1933) RP561.

*"The energy of compression is equal to the area between the compression curve and the thickness axis, that is, the vertical axis. The energy of recovery is the corresponding area for the recovery curve. Unless a planimeter is available, the simplest method of calculating these areas is to divide each area by horizontal lines into a series of trapezoids. The area of each trapezoid is calculated by using the formula 'area equals base times average altitude'—where the base is the distance between the two horizontal lines forming the trapezoid and the average altitude is the average of these two horizontal lines, that is, distance from the thickness axis to their intersection with the curve."

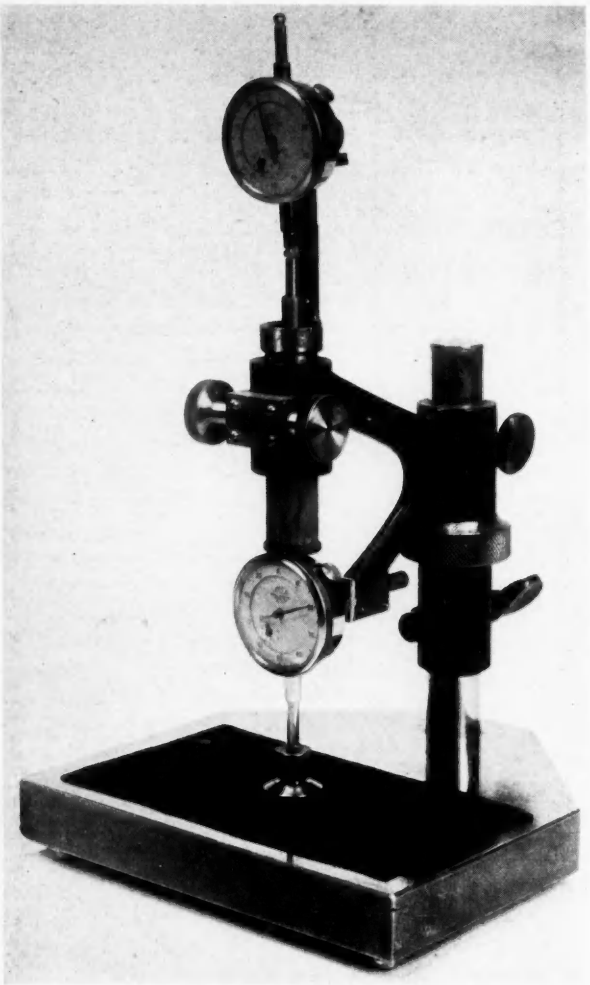


Fig. 1—Compressometer.

with the warp and filling yarns comprising the woven back. The pile yarns are composed of numerous rayon fibers which project a given distance beyond the surface of the back fabric and are oriented substantially perpendicular to it. The load exerted by the compressometer is applied to the ends of the pile fibers, substantially parallel to their longitudinal axes, and tends to bend them over. The amount of bending of the fibers of a given fabric depends upon the number of fibers per unit area, their stiffness and the applied load. The fibers deflect in all directions, and thereby reinforce each other to some degree. However, as the load is increased a value is eventually reached which is greater than can be supported by the pile fibers and a sudden bending over of the fibers at their base results. This collapse of the pile, equivalent to a sudden decrease in the thickness of the fabric, is indicated by an abrupt change in the compression curve. A fabric in which this condition has been produced is here described as having been "crushed."

Typical curves representing the compression and recovery of two transparent velvet fabrics, measured before and after the application of crush-resistant treatments, are plotted in figure 2. They show clearly that the pile of both fabrics before treatment is crushed by pressures less

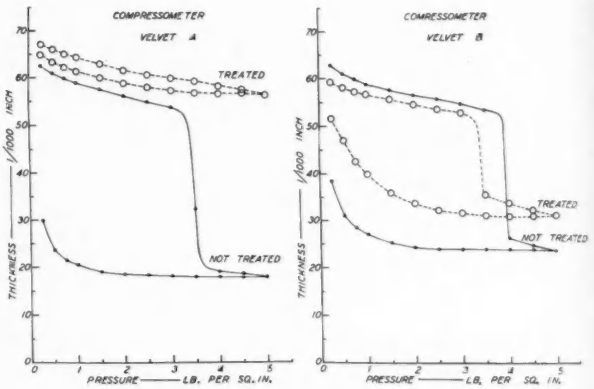


Fig. 2—Effect of crush-resistant finishing treatments on compression and recovery curves of two transparent velvet fabrics as measured by the compressometer.

than 5 pounds per square inch, and that the fabrics do not recover to their original thickness when the load is removed. The treatment applied to fabric A, No. 4 in table 1, has greatly improved it both with respect to the extent of the compression, which is very small for a pressure of 5 pounds per square inch, and with respect to the recovery. The pile of this fabric is not crushed. The improvement in fabric B, No. 5 in Table 1, resulting from the treatment is much less with respect to the compression and recovery and the pile of the treated fabric is crushed.

Two of the six velvet fabrics tested were compressed but little under a pressure of 5 pounds per square inch, either before or after the application of the crush-resistant treatment. The compression and recovery curves of these fabrics are similar to the treated curves of velvet A, figure 2. In two the pile was crushed before but not after the treatment (figure 2, velvet A), while for the remaining two the pile was crushed both before and after the treatment (figure 2, velvet B). The compression and recovery curves obtainable with the compressometer show the differences in these fabrics clearly. It is concluded that the instrument should be useful in evaluating the effectiveness of crush-resistant treatments and in studying variations in them.

In general there was observed a more marked change in appearance between the compressed and uncompressed areas of an untreated velvet fabric than in the treated specimen of the same fabric. This difference in appearance was more permanent in the untreated fabrics. Also, in comparing the six velvet fabrics with each other with respect to appearance, the two untreated velvets in which the pile was not crushed changed less in appearance than

the four untreated velvets in which the pile was crushed. Similarly, the four treated velvets in which the pile was not crushed changed less in appearance than the two treated velvets in which the pile was crushed.

The compressional resilience for each of the six velvet fabrics tested is given in Table 1. This quantity is increased by the crush-resistant finishing treatments. It can be correlated with the change in appearance produced when the compressed areas are compared with areas that have not been compressed. These changes in appearance are also noted in the table.

TABLE 1

Effect of crush-resistant finishing treatments on transparent velvet fabrics

Specimen number	*Designation*	*Compressional resilience*	*Remarks*	*Change in appearance*
		percent		
1	Not treated	38	Pile not crushed	Slight
	Treated	50	Pile not crushed	Very slight
2	Not treated	41	Pile not crushed	Very slight
	Treated	43	Pile not crushed	Very slight
3	Not treated	6	Pile crushed	Great
	Treated	46	Pile not crushed	Very slight
4	Not treated	7	Pile crushed	Very great
	Treated	55	Pile not crushed	Very slight
5	Not treated	9	Pile crushed	Great
	Treated	27	Pile crushed	Slight
6	Not treated	10	Pile crushed	Great
	Treated	17	Pile crushed	Slight

In order to show the effect of crush-resistant treatments on fabrics in which the pile is not crushed under a pressure of 5.0 pounds per square inch, greater maximum pressures would have to be used. Thus it may be found desirable to apply to each specimen tested a maximum pressure just sufficient to crush the pile. The maximum pressure and the values for compressional resilience thus obtained might be more useful for measuring the effects of crush-resistant treatments than the compressional resilience calculated on the same maximum pressure for all fabrics.

Much additional and probably valuable information about crush-resistant treatments could be obtained by systematic studies of the effects of differences in atmospheric humidity, time of application of the loads and time allowed for recovery on fabrics in which such factors as number of pile tufts per square inch, height of pile, number of filaments per tuft, size of the filaments, and finishing treatments are varied systematically. The present work indicates that the compressometer would be useful for such an investigation and the results should be valuable to both manufacturers and users of pile fabrics.

The author acknowledges his indebtedness to Mr. Kenneth Barnard of the Pacific Mills and Chairman of the "Committee on test methods for crease resistance and permanent finishes" of the American Association of Textile Chemists and Colorists, and to Dr. D. H. Powers, who is also a member of the committee for suggestions and interest in this work. Grateful acknowledgment is also made to Röhm and Haas Company, Cheney Brothers, and Rossie Velvet Company for furnishing material for testing

Report of the
Rayon Crepe Research

AS per announcement in the July Quarterly Research issue of the AMERICAN DYESTUFF REPORTER, this number contains a report of the first part of the work of the Rayon Crepe Research. The Committee jointly appointed by the A.A.T.C.C. and the Throwsters Institute which supervised this research was composed of the following members, with B. L. Hathorne acting as chairman: H. E. Bishop, Dr. F. Bonnet, C. W. Dall, C. Epstein, G. Friedlander, E. C. Geier, B. L. Hathorne, J. McGibbon, V. McCullum, Dr. J. B. Quig, Dr. I. J. Saxl, Dr. H. D. Smith, G. A. Urlaub and Wm. Witte.

The active members of this Committee have devoted many evenings to meetings in which the divergent views of the individual members have been reconciled into a composite program, broad enough in scope to cover all of the major variables involved in the problem, yet definite enough in detail to permit an accurate evaluation of the relative importance of the variables involved and to show the effect of increasing and diminishing increments of each variable.

The publication has been approved by the Committee and represents the facts agreed to from the evidence produced by the research.

The actual work of determining the facts and of compiling these facts into intelligible form was carried out by Mr. W. F. Macia, the research fellow chosen by the Committee for this task.

The concise, easily readable report gives no idea of the tremendous amount of actual research that has been carried out on this program involving studies by Mr. Macia in various plants under entirely different sets of conditions, nor does it indicate in any way the magnitude of the task involved. For example, over 100,000 individual tests were made in that part of the report dealing with the rayon itself. Mr. Macia is to be highly commended for the excellence of his presentation.

It is to be hoped that the wealth of detail and the broad scope of this work may serve as an inspiration for other similar cooperative committees to be organized in the future along similar lines.

LOUIS A. OLNEY, *Chairman,*
Research Committee, A.A.T.C.C.

ORIGIN

There have always been some differences of opinion regarding the cause of undesirable variations in fabrics containing rayon crepe yarns, but during the Spring of 1935 the number of complaints and claims increased at such an alarming rate that many manufacturers in all branches of the industry became involved in much unpleasant controversy. There was a general feeling that in many instances the responsibility was accepted even when it had not been clearly established, because the cause, or causes, of the defects or variations in the fabric could not be determined. Representatives from each branch of the industry agreed that the best means of clarifying the situation was to determine as much as possible regarding the normal variations to be expected in rayon crepe fabrics and present these facts in an unbiased manner to the entire industry. The plan was received with much enthusiasm in all branches of the industry directly and indirectly involved in the manufacture of crepe fabric and during the first month of its inception, was endorsed by rayon producers, throwsters, weavers, and dyers and finishers.

The plan was presented to the Throwsters Research Institute whose members comprised a manufacturing group which had suffered heavily by these claims. The Throwsters Research Institute heartily endorsed the plan and took immediate action to bring about its fulfillment.

A temporary committee composed of accredited representatives of each branch of the industry was formed to decide the best plan of procedure. They decided that the only way to obtain the desired facts was to make an extensive research study of all of the processes involved in the manufacture of rayon crepe fabric and present the facts to the entire industry. To arouse general interest in a research study of this kind and to determine the best courses to pursue, the United States Institute for Textile Research, Inc., was asked to hold a symposium on rayon crepe problems. An open conference on this subject was held at the Waldorf-Astoria Hotel, New York, on November 14, 1935, by the United States Institute for Textile Research, Inc. The subject of the conference as described at the time was as follows: "Its purpose is to provide for an exchange of views on the various problems connected with the manufacture of crepe fabric from rayon yarns, with the object of obtaining such a broad and thorough conception of the nature and the extent of these problems that a comprehensive and a practical plan of cooperative research can be worked out, if it is found advisable."

The Rayon Crepe Research is divided into seven parts which are all closely related. This work will be published serially in the Quarterly Research Numbers of the Dyestuff Reporter.

This issue contains: (1) the results of a survey made in numerous throwing and weaving plants to determine the limitations and extent of variations in each mechanical process in the commercial manufacture of 200 denier rayon crepe yarns and to determine average methods to use in subsequent work; (2) a supplementary survey of plants operating on 75, 100 and 150 denier rayon crepe yarn; and (3) an investigation which included a comparison of the winding qualities of rayon skeins in a rayon producing plant and a throwing plant.

The later issues will contain: (4) the results of an investigation of the possibility of making uniform rayon crepe fabrics from normal deliveries of rayon yarns; (5) the results of an investigation of the relative importance of variations in each process in the manufacture of rayon crepe dress fabrics; (6) an investigation of the variations in normal deliveries of raw rayon yarns; and (7) an investigation of the influences of variations in the dyeing and finishing operations upon the finished fabric.

The work in each part of this program is so closely related that the readers are cautioned against drawing conclusions on the basis of the results of the individual parts. The Rayon Crepe Research Committee will correlate all of the data and publish their conclusions in the last issue.

The meeting was well attended by representatives of all branches of the industry and much value was derived from the open discussion of their problems and experiences.

The meeting indicated that a research program could be of great benefit to all involved in the manufacture and fabrication of rayon crepe yarn. At the same time it would allow a good opportunity of determining the relative importance of each of the many variables affecting finished crepe fabric and would undoubtedly lead to the development of new facts which might eliminate many of the variations. The Rayon Crepe Research Committee appreciates the services rendered by the United States Institute for Textile Research, Inc.

The financing of the rayon crepe research program was made possible through a grant from the Textile Foundation, Inc. to the American Association of Textile Chemists and Colorists. This grant was matched by contributions raised by the Throwsters Research Institute, Inc. from the industry and generous donations from their own treasury. (A complete list of contributors will be published later.) The funds were to be expended in a joint rayon crepe research program guided by the Rayon Sub-Committee of the American Association of Textile Chemists and Colorists and the Throwsters Research Institute, Inc. The Rayon Crepe Research Committee extend their thanks to the Textile Foundation, Inc., American Association of Textile Chemists and Colorists, Throwsters Research Institute, Inc. and the industrial contributors for their generous support of this project.

A Committee consisting of the following members was chosen from each of the organizations:

Member	*Firm*	*Representing*
Dr. F. Bonnet,	American Viscose Corporation,	A.A.T.C.C.
B. L. Hathorne,	Berkeley Products, Inc.,	A.A.T.C.C.
V. McCullum,	National Dyeing & Printing Co.,	A.A.T.C.C.
Dr. J. B. Quig,	E. I. du Pont de Nemours & Co.,	A.A.T.C.C.
Dr. H. D. Smith,	A. M. Tenney Associates,	A.A.T.C.C.
Wm. Witte,	National Dyeing & Printing Co.,	A.A.T.C.C.
H. E. Bishop,	Bliss Silk Throwing Co.,	T.R.I.
C. W. Dall,	National Rayon Weavers Association,	T.R.I.
C. M. Epstein,	Liberty Throwing Co.,	T.R.I.
G. Friedlander,	Duplan Silk Corporation,	T.R.I.
E. C. Geier,	Duplan Silk Corporation,	T.R.I.
Dr. I. J. Saxl,	E. F. Houghton & Company,	T.R.I.
G. A. Urlaub,	Throwsters Research Institute, Inc.,	T.R.I.

The committee meetings were held in an informal friendly manner and members discussed freely respective views. The program itself was the subject of many long tedious meetings of the Committee and when it was finally put into operation had the approval of the entire Committee. The aims of the final program were as follows:

"The object of this entire program is to prove the extent to which variations within each individual phase of the manufacture of finished crepe fabric from the production of the rayon itself through the throwing, weaving, and dyeing and finishing operations, manifest themselves as visible variations in finished merchandise.

"It also includes a study of the limitations of each of the various steps in the process; namely, a determination of the inherent variables in normal processes and equipment."

There are numerous yarns of different denier and all kinds of fabric constructions on the market but the great amount of work in this research precluded the possibility of investigating more than one denier size of filling crepe yarn and one fabric construction. One of the principal fabrics which had been very susceptible to variations in pebble elevation and character was constructed with 96 warp ends of 150 denier Acetate yarn and 48 picks of 200 denier Viscose type yarn. It was, therefore, decided to confine this research to this fabric construction and 200 denier viscose type filling yarn.

When a small part of the work of this research was completed and the results presented to the Committee, it was obvious that partial publication of the results might incur penalties on one or more of the participating groups. It was, therefore, decided that publication of the results would be withheld until sufficient work had been completed to furnish some basis for reasonable conclusions and that the data would first receive the approval of the entire Committee before being published.

In the following pages will be found a detailed presentation of the results of the research together with some detailed explanations of the reasons for each step, detailed description of the manner in which each step was carried out, and such specific conclusions as could be drawn from the data. It was not intended to theorize in this report but to present to the industry a clear description of the work performed, and the specific results obtained and to offer recommendations which will be of most benefit to the industry in general.

I—A Survey of the Commercial Methods of Processing Rayon Crepe Yarns in Throwing and Weaving Plants

INTRODUCTION

ONE of the primary objects of the rayon crepe research was to determine the limitations and extent of variations in each individual mechanical process in the commercial manufacture of rayon crepe yarns. This survey was made to find (1) the control being exercised by some of the best throwsters and weavers on mechanical equipment considered normal today; (2) the variations which exist upon equipment in use; (3) the limits within which each process could be controlled; and (4) to find methods representing the best practices used in commercial processing of rayon crepe yarns which were in turn used as a basis for subsequent work in this research.

SUMMARY

The first work in connection with the Rayon Crepe Research was to determine the variations of each of the various mechanical steps in the processing of rayon crepe yarn in normal throwing and weaving plants and to find methods representing the best practices in the commercial processing of rayon crepe yarns which in turn could be used as a basis for subsequent work in this research. A survey was made in seven throwing plants and four weaving plants operating on 200 denier commercial viscose type rayon. Records were made of the type of machinery and equipment used in each plant, the operating speeds, the atmospheric conditions, the tension or strain on the yarn during operation, and numerous other details.

This survey showed that there are numerous variations in all of the mechanical operations in throwing and weaving plants. In most instances the variations were unavoidable even with the most careful supervision because with the present equipment it is almost impossible for throwsters and weavers to control their mechanical processes any closer without some radical improvement in their machinery. As more information becomes available regarding the actual influences of variations in the mechanical operations upon the production and quality of the finished fabric this knowledge will be utilized by the machine makers to the advantage of the entire industry. As it will probably be some time before the necessary changes in equipment and machinery can be made to bring about more positive control, it is suggested that every possible effort be devoted to reducing the existing variations by any means best suited to the individual manufacturer.

From the data in this survey the following methods and equipment were selected to be used as a basis for the processing of yarns in later work in this research:

Winding Operation:

Type of machines	Atwood or Sipp-Eastwood
Type of swifts	Atwood, wire
Weight on swift axles	Sufficient to give the desired tension on the yarn
Length of yarn under strain	18" to 22"
Average Relative Humidity	55.0%
Yarn running speed (Yds. per Min.)	Minimum 117 Maximum 199
Tension or strain on the yarn for extreme experiments	Average—30 to 50 grams Low—10 to 30 grams High—50 to 70 grams

Twisting or Throwing Process:

Make of machines	Atwood
Flyer: Type—4 arm mill nut Make—McHale Weight Sufficient to give desired tension on the yarn	
Length of yarn under strain	12"
Spindle speeds	10,000 R.P.M.
Average Relative Humidity	55.0%
Tension or strain on the yarn for extreme experiments	Average—18 to 35 grams Low—0 to 18 grams High—45 to 65 grams

Redrawing Operation:

Make of machines	Optional
Length of yarn under strain	22"
Yarn running speeds (Yds. per Min.)	Minimum—106 Maximum—229
Tension or strain on the yarn for extreme experiments	Average—25 to 45 grams Low—5 to 25 grams High—45 to 65 grams
Average Relative Humidity	55.0%

Copping Operation:

Make of machines	Universal
Average Relative Humidity	55.0%
Tension or strain on the yarn for extreme experiments	Average—50 to 70 grams Low—30 to 50 grams High—70 to 90 grams

SCOPE OF WORK IN THE SURVEY OF THE THROWING AND WEAVING PLANTS

The work in this part of the research was done in seven throwing plants and four weaving plants which were operating on commercial 200 denier Viscose type rayon. Per-

mission was granted by the companies to enter the plants and conduct the surveys and in return, the principals were given the results of the findings in their own plants. All the measurements were made, at random, by the Research Fellow.

The study included all of the mechanical operations through which the yarn passed from the rayon as received from the producer to the woven fabric. The following factors were included in the study of the winding operation: make of machine, type of swifts, weight on swifts, length of yarn under strain, atmospheric conditions, yarn running speed, strain or tension on the yarn and the density or hardness of the full spools. In the study of the twisting or throwing operation the following factors were included: make of machines, make, type and weight of flyers, twist, length of yarn under strain, spindle speed, atmospheric conditions and the strain or tension on the yarn. In the study of the redrawing operation the following factors were included: make of machines length of yarn under strain, yarn running speed, atmospheric conditions, strain or tension on the yarn, and the density or hardness of the full spools. The study of the copping or quilling operation included the following: make of machines, atmospheric conditions, strain or tension on the yarn and the density or hardness of the cops.

METHODS AND INSTRUMENTS USED

The instruments used in this survey were the best available for their purposes. Although they were limited in their scientific accuracy they are in general use in mill practice. The measurements requiring no instruments, or for which none are available were made according to the best judgment of the Research Fellow.

Temperature and Humidity

Five observations were made of the temperature and humidity around the locality of the machine being studied. A standard 12″ sling Psychrometer was used.

Yarn Running Speed

The linear running speed of the yarn in winding was determined by accurately counting the r.p.m. of the swifts and measuring the circumference of the skeins at five different intervals. Since the speed varied with the sizes of the skeins and spools, the average was obtained by measurements at the following intervals:

Skein	*Spool*
Full	Empty
¾ Full	¼ Full
½ Full	½ Full
¼ Full	¾ Full
Almost Run Out	Almost Full

The linear speed of the redrawing operation was calculated from the speed of the drawing frame main shafts, and the diameters of the contact and spindle pulleys. In most plants, cork spindle pulleys were used so the frictional loss was small, therefore, the calculated speed of the drawing spools was always constant. The only variation in linear speed was produced by the "build up" of the yarn on the spool, which changed the spool diameter. An average was obtained by calculating the linear yarn speed at five diameters of the drawing spool.

Strain or Tension on the Yarn

The tension or strain on the yarn was determined by applying a tension meter to the yarn while it was in motion. Two types of instruments were used, a Sipp-Eastwood and Alfred Suter (imported). Both instruments were periodically checked and were found to be accurate and give corresponding readings on the same ends. Fluctuations in the tension were observed on every end, in all the processes, but only the maximum tension observed was recorded in each individual measurement. Taking of the measurements was distributed, at random, over several machines operating on the same yarn.

Density or Hardness of Full Spools

The density of the full spools was determined by applying a density or hardness meter (Durometer-Shore Instrument Company).

The density instrument measures the hardness and uniformity of hardness of the full spools while the density of the spools indicates the uniformity of end to end tension in the individual plant.

The traverse, fullness of the spools, humidity and diameter of spool barrels influence the density to such an extent that comparisons cannot be made between two plants, so, it is necessary to confine the comparisons to individual plants.

Spindle Speeds

The spindle speeds in twisting were determined by stroboscopic observations. It was found that the mills included in this survey kept a constant control over this factor and a regular system of policing was maintained in each plant, because any variation from spindle to spindle would cause uneven twist. In this survey no irregularities in spindle speed were found from spindle to spindle and the differences from machine to machine were so minute that no records were kept of these differences.

RESULTS OF SURVEY

The individual measurements in this survey were so numerous that space here would not permit the publication of each one. By preparing charts and tables the data have been condensed as much as possible without any loss in value.

TABLE 1
Summary of the General Data Gathered in the Survey of the Winding Operation

Plant No.	Make of Machines	Type of Swifts	Weight on Swift Axles	Length of Yarn Under Strain	Aver. Temp.	Aver. Humidity	Yarn Running Speed (Yds. per Min.) Min.	Max.
A	Atwood Double-Deck	Atwood, Wire	16 oz.	24″	74° F.	59%	115	182
B	Sipp-Eastwood	Atwood, Wire	15 oz.	19″	73° F.	55%	127	245
C	Atwood	Atwood, Wood	24 oz.	22″	82° F.	45%	105	192
D	Atwood Double-Deck	Atwood, Wire	15 oz.	18″	79° F.	55%	110	187
E	Sipp-Eastwood	Wood	12 oz.	23″	80° F.	48%	128	206
F	Sipp-Eastwood	Wood, Metal, Cradle	11 oz.	21″	78° F.	56%	157	257
G	Atwood	Atwood, Wire	17½ oz.	22″	75° F.	40%	76	122

TABLE 2
Winding Tensions

Tension (Grams)	Plant A	B	C	D	E	F	G	Total Ends
11 to 15					1			1
16 to 20					24		1	25
21 to 25	1	1			66		8	76
26 to 30	2	35		10	79	1	31	158
31 to 35	14	92	14	43	27	28	41	259
36 to 40	37	55	39	65	3	57	43	299
41 to 45	68	15	55	50		68	32	288
46 to 50	34	2	39	18		35	21	149
51 to 55	25		27	13		7	10	82
56 to 60	13		15	1		4	9	42
61 to 65	5	8					3	16
66 to 70	1	3					1	5
	200	200	200	200	200	200	200	1,400

This table includes all of the measurements made of the strain on 200 denier yarn in the winding operation in seven throwing plants. Two hundred ends were measured in each plant.

As a matter of explanation, it will be observed that the table shows that in plant "A" the tension varied from 21 to 70 grams. It also shows the frequency or number of ends being operated within definite ranges of tension, for instance, there was only one end out of the 200 measured that was being wound within the range of 21 to 25 grams tension, whereas, there were 68 ends being wound within the range of 41 and 45 grams tension.

TABLE 3
Density of Winding Spools

Density*	Plant A	B	C	D	E	F	G	Total Spools
21 to 30	4				40			44
31 to 40	75		17	2	132	3	44	273
41 to 50	100		87	14	28	84	80	393
51 to 60	21	79	80	27		108	66	451
61 to 70		121	16	85		5	10	237
71 to 80				2				2
	200	200	200	200	200	200	200	1,400

This table includes all of the measurements made of the density of the winding spools in seven throwing plants. The table shows the frequency or number of spools of various hardness and the total variations in each plant.

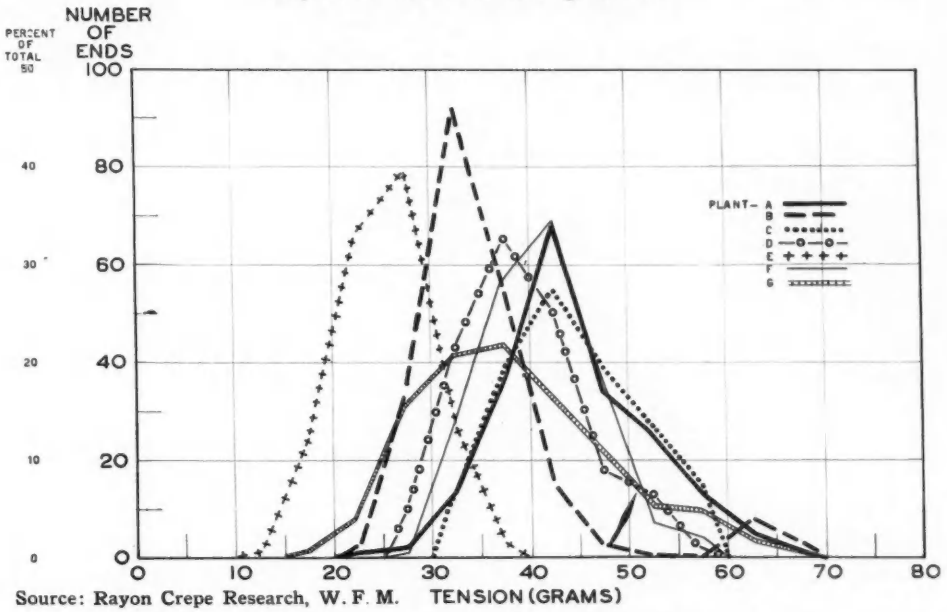
*Arbitrary values.

TABLE 4
Summary of the General Data Gathered in the Survey of the Twisting or Throwing Operation

Plant No.	Twist	Make of Spinners	Flyers Type	Flyers Make	Flyers Weight	Length of Yarn Under Strain	Spindle Speed	Temp.	Humidity
A	48	Atwood Double Deck	4 Arm Cam Eccentric	McHale	No. 11 Wire	12″	9,650	87° F.	52%
B	45	U. S. Textile Mach. Co. Double Deck	4 Arm Cam Eccentric	McHale	No. 10 Wire	13″	10,600	77° F.	62%
C	50	Atwood Single Deck	4 Arm Mill Nut	McHale	No. 10 Wire	15″	11,800	86° F.	40%
D	46	Atwood Double Deck	4 Arm Mill Nut	McHale	No. 12 Wire	12″	10,200	82° F.	51%
E	48	Atwood Double Deck	4 Arm Mill Nut	Collins	No. 9 Wire	13″	9,400	91° F.	46%
F	44	Atwood Double Deck	4 Arm Mill Nut	Collins	No. 10 Wire	13″	9,800	88° F.	52%
G	45	Atwood Double Deck	4 Arm Mill Nut	McHale	No. 9 Wire	12″	9,400	85° F.	32%

CHART-2

Frequency Distribution of the Winding Tensions Used on 200 Denier Viscose Type Rayon in Seven Throwing Plants

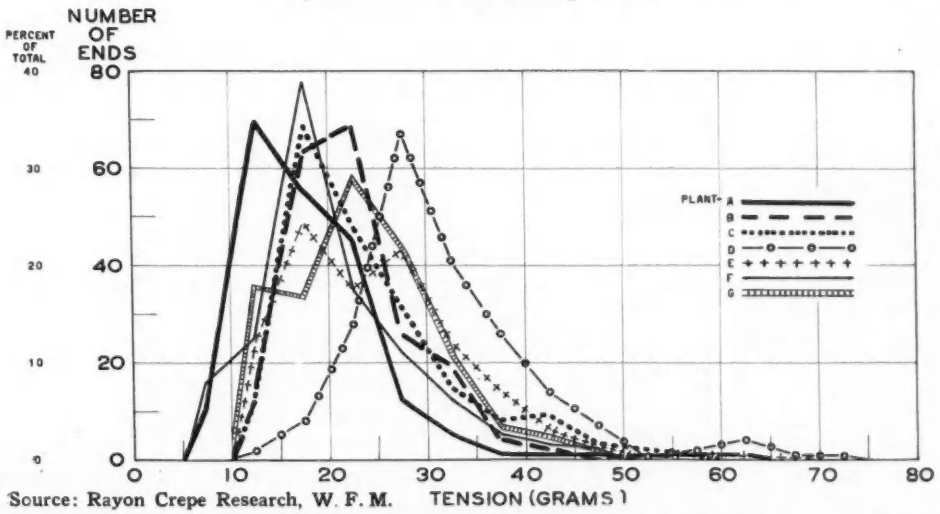


Source: Rayon Crepe Research, W. F. M.

This chart shows the total variations in tension within each plant, the frequency or number of ends operated within various ranges of tension and the differences in tension between plants. This chart was plotted from the data in Table 2.

CHART-5

Frequency Distribution of the Twisting Tensions Used on 200 Denier Viscose Type Rayon in Seven Throwing Plants



Source: Rayon Crepe Research, W. F. M.

This chart shows the total variations in tension within each plant, the frequency or number of ends operated within various ranges of tension and the differences in tension between plants. This chart was plotted from the data in Table 5.

TABLE 5
Twisting Tensions

Tension (Grams)	Plant A	B	C	D	E	F	G	Total Ends
6 to 10	11					16		27
11 to 15	70	14	14	2	24	25	35	184
16 to 20	54	63	69	8	49	78	33	354
21 to 25	45	69	48	28	35	35	57	317
26 to 30	12	26	31	67	43	22	43	244
31 to 35	5	19	15	41	24	12	21	137
36 to 40	1	4	8	26	14	5	6	64
41 to 45	1	2	9	14	6	2	4	38
46 to 50	1		3	7	3	4	1	19
51 to 55		1	2		1			4
56 to 60		1	1	1		1		4
61 to 65		1		4				5
66 to 70				1	1			2
71 to 75				1				1
	200	200	200	200	200	200	200	1,400

This table includes all of the measurements made of the strain on 200 denier yarn in the twisting or throwing operation in seven throwing plants. Two hundred ends were measured in each plant. This table shows the total variations within each plant, the frequency or number of ends operated within various ranges of tension, and the differences in tension between plants.

TABLE 6
Summary of the General Data Gathered in the Survey of the Redrawing Operation

Plant No.	Make of Machines	Length of Yarn Under Strain	Yarn Running Speed (Yds. Per Minute) Minimum	Maximum	Average Temp.	Average Humidity
A	Atwood ...	28"	67	141	76° F.	57%
B	U. S. Textile Mach. Co...	28"	168	352	77° F.	59%
C	Atwood ...	17"	104	220	78° F.	51%
D	Atwood ...	17"	146	308	77° F.	52%
E	Fletcher ...	18"	90	202	83° F.	49%
F	Fletcher ...	18"	105	240	79° F.	68%
G	Atwood ...	25"	67	140	71° F.	55%

TABLE 7
Redrawing Tensions

Tension (Grams)	Plant A	B	C	D	E	F	G	Total Ends
11 to 15			2					2
16 to 20	1		17	18	13			49
21 to 25	3	1	61	65	49	12	6	197
26 to 30	18	24	65	67	85	32	22	313
31 to 35	49	60	28	38	40	49	61	325
36 to 40	52	52	22	7	13	55	64	265
41 to 45	42	47	1	3		29	33	155
46 to 50	16	15	4	1		17	14	65
51 to 55	12	3		1		4		20
56 to 60	1							1
61 to 65	5					2		1
66 to 70	1							1
	200	200	200	200	200	200	200	1,400

This table includes all of the measurements made of the strain on 200 denier yarn in the redrawing operation in seven throwing plants. Two hundred ends were measured in each plant. This table shows the total variations within each plant, the frequency or number of ends operated within various ranges of tension, and the differences in tension between plants.

TABLE 8
Density of Redrawing (Shipping) Spools

Density	Plant A	B	C	D	E	F	G	Total Spools
11 to 20			1					1
21 to 30			31		1	1		33
31 to 40	72		100	38	10	11	2	233
41 to 50	108		54	122	123	36	19	462
51 to 60	18	35	12	40	63	130	71	369
61 to 70	2	25	2		3	22	8	62
	200	60	200	200	200	200	100	1,160

This table includes all the measurements made of the density of the redrawing spools in seven throwing plants. The table shows the frequency or number of spools of various hardness and the total variations in each plant.

TABLE 9
Summary of the General Data Gathered in the Survey of the Copping or Quilling Operation

Plant No.	Make of Machines	Temp.	Relative Humidity
H	Universal	75° F.	59%
J	Universal	76° F.	45%
K	Universal	83° F.	53%
L	Universal	77° F.	71%

TABLE 10
Copping (Quilling) Tensions

Tension (Grams)	H	J	K	L	Total Ends
31 to 35				2	2
36 to 40				10	10
41 to 45				23	23
46 to 50		2	1	18	21
51 to 55		3	8	16	27
56 to 60	9	12	35	4	60
61 to 65	81	23	25	6	138
66 to 70	91	29	10	1	131
71 to 75	11	12	1		24
76 to 80	8	16			24
	200	100	80	80	460

This table includes all of the measurements made of the strain or tension on 200 denier yarn in the copping operation in four weaving plants. This table shows the total variations within each plant, the frequency or number of ends operated within various ranges of tension and the differences in tension between plants.

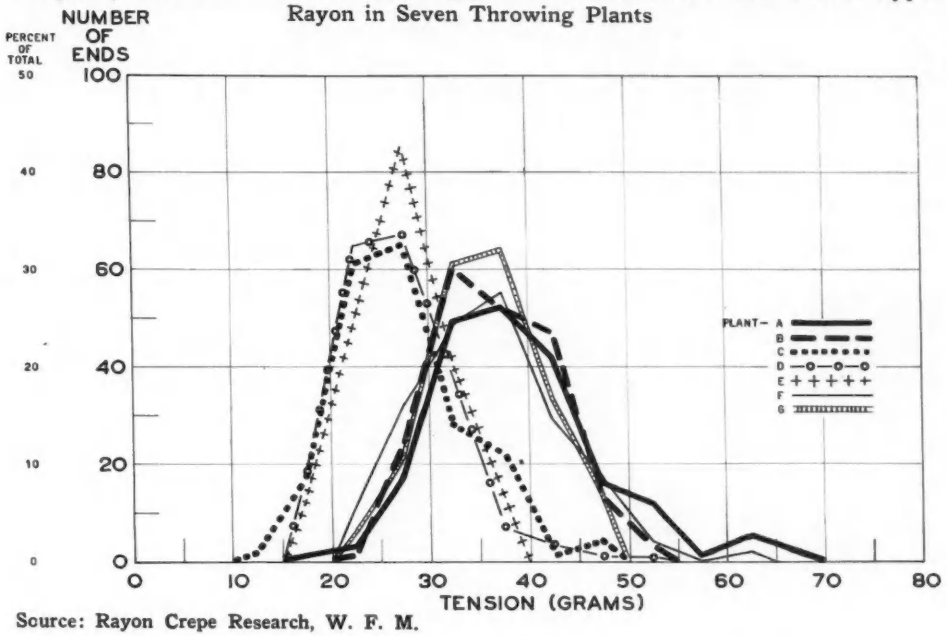
TABLE 11
Density of Cops or Quills

Density	Plant H	J	K	L	Total Cops
61 to 70	22		38	50	110
71 to 80	78	43	42	30	193
81 to 90		32			32
	100	75	80	80	335

This table includes all of the measurements made of the density of cops or quills in four weaving plants. The table shows the frequency or number of cops of various hardness and the total variations in each plant.

CHART-7

Frequency Distribution of the Redrawing Tensions Used in 200 Denier Viscose Type Rayon in Seven Throwing Plants

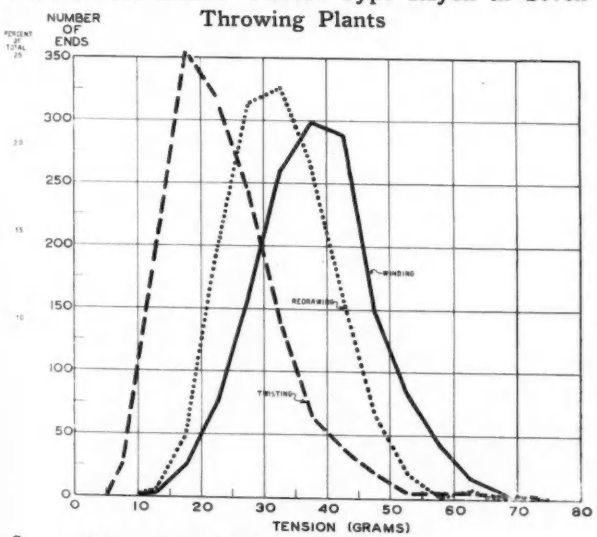


Source: Rayon Crepe Research, W. F. M.

This chart shows the total variations in tension within each plant, the frequency or number of ends operated within various ranges of tension and the differences in tension between plants. This chart was plotted from the data in Table 7.

CHART-8

Frequency Distribution of the Winding, Twisting and Redrawing Tensions Used on 200 Denier Viscose Type Rayon in Seven Throwing Plants



Source: Rayon Crepe Research, W. F. M.

All of the tension measurements made in 7 throwing plants were plotted on this chart. Each curve represents 1,400 measurements in each operation. The chart shows the frequency, or number of ends operated within various ranges of tension; and the total variation in each operation. This chart was plotted from the data in Tables 2, 5 and 7.

DISCUSSION OF RESULTS

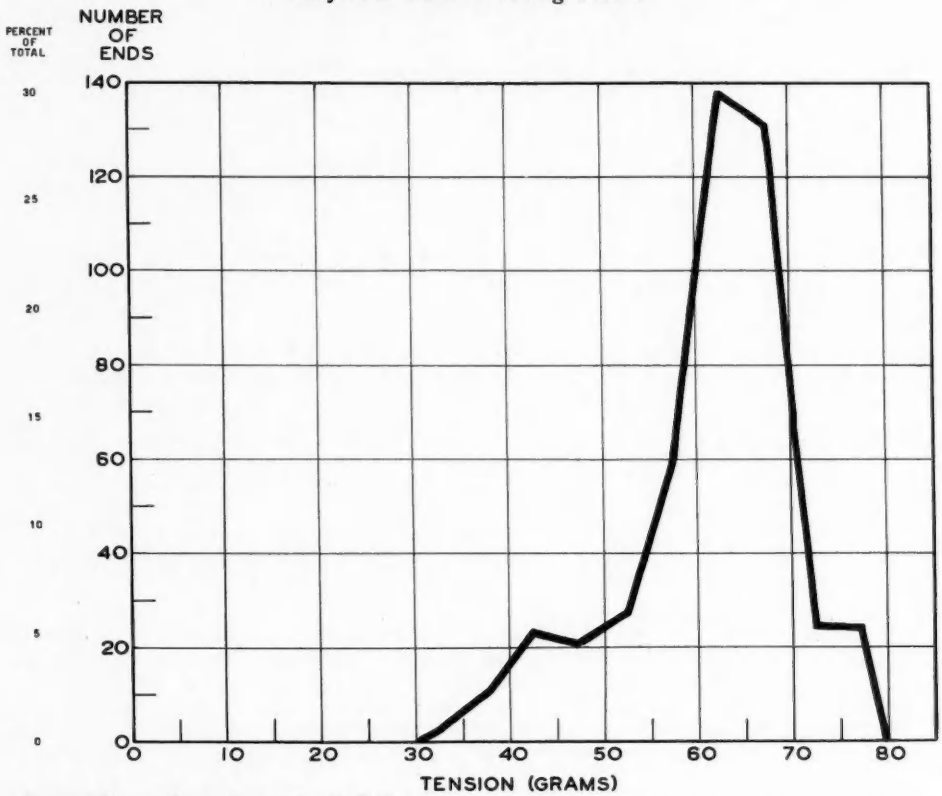
It has been previously mentioned that one of the primary objects of this research was to determine the limitations and extent of variations in the mechanical processes in the manufacture of rayon crepe yarns and that this part of the research was devoted to an investigation of the mechanical processes in numerous throwing and weaving plants to find (1) the control being exercised by some of the best throwsters and weavers; (2) the existing variations in mechanical equipment considered normal today; (3) the limits within which each process could be controlled; and (4) the average methods used in processing 200 denier rayon crepe yarn in modern throwing plants which were used as a basis for subsequent work in this research.

Much of the data presented are self explanatory insofar as showing (1) the amount of control exercised by some of the best throwsters and weavers and (2) the existing variations in normal mechanical equipment. In later work in this research some of the important variations have been carefully investigated and their influence upon the finished fabric has been determined.

The results of this survey have been discussed in detail to assist in their interpretation and understanding and to explain some of the difficulties and limitations of the mechanical phases of the rayon crepe throwing and weaving industry. It is hoped that this information will benefit the industry in general.

CHART 10

Frequency Distribution of the Copping Tensions Used on 200 Denier Viscose Type Rayon in Four Weaving Plants



Source: Rayon Crepe Research, W. F. M.

All of the tension measurements made in four weaving plants were grouped and plotted on this chart. The curve represents 460 measurements. The chart shows the frequency or number of ends operated within various ranges of tension and the total variations in the four plants. This chart was plotted from the data in Table 10.

Winding Operation

The purpose of the winding operation in throwing plants is to transfer the yarn from skeins to spools or to prepare the yarn for twisting or throwing.

The general methods of winding rayon crepe yarn were found to be the same in all of the plants in this survey. In the summary of the general data gathered in the survey of the winding operation it will be observed that four of the seven plants used wire type swifts.

The weights used on the axles of the swifts were found to be different in each plant, the amount of weight used depended upon the conditions within the individual plants.

The length of yarn under strain or the distance from the outside of the swifts to the bobbin was found to be different in each plant. This distance was regulated by the individual winding equipment and on many machines was a fixed distance, athough some machines had adjustable arms by which the swifts could be raised or lowered.

The atmospheric conditions in the winding operation were found to be different in each plant in this survey. The plants having the most modern type of humidity equipment tried to maintain the relative humidity between fifty and sixty per cent. All the plants in this survey had some means of humidifying but only one plant had means of de-humidifying.

The yarn running speed in winding was found to be different in each plant. The speed was governed by the experiences of the individual plants and type of equipment used.

The tension used on the yarn during winding was very nearly the same in each plant in this survey except in one instance. Plant "E" operated with very much less tension.

Tension tests were made on 200 ends in each plant in the winding operation or on 1400 ends in the 7 plants. A composite of all the plants showed that the total range extended from 11 to 70 grams, although 1235 ends or 88.2 per cent were being operated within the range of 21 to 56 grams. (Refer to Table No. 2).

It will be observed that the tension used on the ends in winding in plant "A" varied from 21 to 70 grams although the majority of the ends were operated within a range of tension from 31 to 60 grams.

In plant "B" the tension on the ends in winding varied from 21 to 70 grams but most of the ends were being operated within the range of 26 to 45 grams tension.

In plant "C" all of the ends measured were operated within the comparatively narrow range of tension of 31 to 60 grams.

The tension in winding plant "G" was found to ex-found to range from 26 to 60 grams although the majority of the ends were operated between 31 and 50 grams.

The winding tensions in plant "E" ranged from 11 to 40 grams, whereas the majority of the ends were operated within a range of 16 to 35 grams.

In plant "F" the tension on the yarn in winding extended from 26 to 60 grams although the majority of the ends were operated between 21 and 50 grams.

The tension in winding in plant "G" was found to extend from 16 to 70 grams although the majority of the ends were operated between 26 and 55 grams.

Table No. 3 shows the hardness of 200 winding spools in each plant in this survey. It will be observed that plant "B" had the least amount of variation in the hardness from spool to spool, all 200 spools being between 51 and 70 density.

Twisting

The twist is inserted in the yarn in the twisting or throwing process. The spools containing the yarn from the winding operation are placed on the spindles of the twisters and the yarn is drawn off by a take-up shaft or spool while the twist is being put in. The rapidity with which the yarn is drawn off in relation to the spindle speeds regulates the number of turns of twist inserted.

Uniformity of speed from spindle to spindle is essential and the take-up shafts or spools must revolve at a positively uniform speed or there will be differences in twist from end to end. All the modern throwing plants have set up a system of policing the spindle speeds so that any variation in speed which develops due to mechanical wear is immediately corrected.

Table No. 4 shows that 6 of the 7 plants in this survey used the same make of twisters.

The mill nut type of flyers were used in 5 of the 7 mills in this survey. The other two used the cam eccentric type which fits into the spool ferrule.

The two major factors which influence the production and quality of yarn produced in twisting are the flyers and the manner in which the winding spools are wound. The flyer only acts as a guide for the yarn as it is being drawn off the spools yet it constitutes one of the big problems of the rayon crepe throwing industry.

There has always been much discussion about the best type and weight flyer to use in twisting rayon crepe but no standards can be established because of slight differences from plant to plant. Differences of spool sizes, spindle lengths and spindle speeds make it imperative that each plant use the flyer best suited to its individual equipment.

Regardless of the type of flyer used, the most important factor to be considered is the amount and the uniformity of strain which the flyer exerts on the yarn, from spool to spool and within the running of one spool. To date there are no flyers available which are perfect in every respect.

There is such a close relation between the flyers used and the tension exerted on the yarn that one cannot be discussed without the other. It will be observed both in table No. 5 and chart No. 5 that the tensions used in twisting in the different plants were nearly the same. The majority of ends, or 93 per cent, were being operated between 11 and 40 grams, in fact 1300 out of the 1400 ends measured were found to be in this range. Only 12 ends out of the 1400 measured were being operated with tension exceeding 55 grams.

Four out of seven plants in this survey attempted to maintain the relative humidity between 50 to 60 per cent in the twisting operation while 3 of the plants maintained a lower degree of humidity.

Redrawing Operation

The purpose of the redrawing operation is only to transfer yarn from the take-up shafts to a suitable shipping spool and to remove from the yarn any extraneous matter such as lumps or large knots.

In this survey it was found that various types of redrawing machines were used by the different plants, although the principle of their operation was the same in each plant. There were differences from plant to plant in the length of yarn under strain and the running speed of yarn. Six of the seven plants maintained the relative humidity in this operation above 50 per cent.

Regardless of the wide differences in equipment and speeds between the different plants in this survey, it was found that most of the plants used nearly the same tension on the yarn. Out of the 1400 measurements made in this survey, it was found that the majority of ends were being operated within the range of 21 and 50 grams tension.

The variations in the tension in redrawing within the individual plants were not as great as either the twisting or winding operations, although the tension on the ends in plant "A" extended from 16 to 70 grams and in plant "F", the tension extended from 21 to 63 grams. Only a very small number of ends in both these plants were operated at a tension exceeding 50 grams.

There was considerable variation in the hardness of the redrawing spools within the individual plants. In plant "C" the density ranged from 11 to 70. In most cases these variations in hardness were due to improper tension devices used on the redrawing machines. With a few minor changes these variations could be considerably reduced but at present there are no tension devices available which make it possible to operate each end absolutely the same in this process.

Copping Or Quilling Operation

A survey was made in four weaving plants of the copping or quilling operation. In the four plants in the survey, the same type machines were used. It will be observed in Table 9 that the humidity was quite different from plant to plant. The tension used in the copping operation in three of the four weaving plants in this survey was much higher than the tensions used in the throwing plants.

The majority of the ends in this survey were found to be operated between 51 and 75 grams tension. The tension, however, within individual plants did not vary as much as in the throwing processes. In plant "L", variations were found to extend from 31 to 70 grams which was a little greater than in the other three plants.

In the average plant it is necessary to use considerable tension in copping to make cops which will weave properly. A 200 denier yarn has a tendency to be very lively and unless the cops are made real hard and are properly wound, the yarn will "sluff" off in the shuttles in bunches and seriously damage the cloth. This has been one of the big problems in weaving 200 denier yarn but has now been overcome in most of the weaving plants.

As in the throwing processes, it is important that all ends be operated as uniformly as possible. The average plant has done all it probably could to bring this about but has been handicapped by the construction of its machines. Further refinement of the copping equipment should be desired to reduce or eliminate the variations and fluctuations in tension in this process.

Representative Methods Found In Survey

One of the reasons for making this survey was to find representative commercial methods of processing rayon crepe yarns. In the research work to be described in subsequent parts of this report the information provided by this survey was used as a guide in determining the effects and relative importance of variations in each process.

After reviewing the data in this survey the following equipment and methods were selected to be used as a basis for the processing of the lots of yarn in the later work.

Winding Operation:

Type of machines	Atwood or Sipp-Eastwood
Type of swifts	Atwood, wire
Weight on swift axles	Sufficient to give the desired tension on the yarn
Length of yarn under strain	18" to 22"
Average Relative Humidity	55.0%
Yarn running speed (Yds. per Min.)	Minimum 117 Maximum 199
Tension or strain on the yarn for extreme experiments	Average—30 to 50 grams Low—10 to 30 grams High—50 to 70 grams

Twisting or Throwing Process:

Make of machines	Atwood
Flyer:	
Type—4 arm mill nut	
Make—McHale	
Weight Sufficient to give desired tension on the yarn	
Length of yarn under strain	12"
Spindle speeds	10,000 R.P.M.
Average Relative Humidity	55.0%
Tension or strain on the yarn for extreme experiments	Average—18 to 35 grams Low—0 to 18 grams High—45 to 65 grams

Redrawing Operation:

Make of machines	Optional
Length of yarn under strain	22"
Yarn running speeds (Yds. per Min.)	Minimum—106 Maximum—229
Tension or strain on the yarn for extreme experiments	Average—25 to 45 grams Low—5 to 25 grams High—45 to 65 grams
Average Relative Humidity	55.0%

Copping Operation:

Make of machines	Universal
Average Relative Humidity	55.0%
Tension or strain on the yarn for extreme experiments	Average—50 to 70 grams Low—30 to 50 grams High—70 to 90 grams

II—A Supplementary Survey of the Commercial Methods of Processing Rayon Crepe Yarn in Throwing Plants

IN connection with the survey of the commercial methods of processing 200 denier rayon crepe yarns a survey was also made in five throwing plants which were operating on 75 denier, 100 denier and 150 denier Viscose type rayon.

The data collected in these five throwing plants cannot be correlated with the subsequent findings in this research because the major part of the work was done on 200 denier yarn.

The measurements taken in this part of the survey were made with the same painstaking effort as those taken in the plants operating on 200 denier yarn, therefore, they can be considered of much value for comparative purposes.

Numerous charts and tables have been prepared of the data gathered in these plants and they are offered without any explanations because most of the data is self-explanatory if the results of the survey of the plants operating on 200 denier yarn are reviewed.

TABLE 12
Summary of the General Data Gathered in the Survey of the Winding Operation

Plant No.	Make of Machines	Type of Swifts	Weight on Swifts	Length of Yarn Under Strain	Average Temp.	Average Humidity	Yarn Running Speed (Yds. per Minute) Minimum	Maximum	Denier Yarn
M	Atwood	Atwood, Wood	18 oz.	19″	67° F.	69%	111	171	150
N	Atwood	Atwood, Wire	12 oz.	24″	73° F.	55%	131	199	150
O	Atwood	Atwood, Wire, Ideal	12 oz.	17″	80° F.	32%	75	111	100
P	Sipp-Eastwood	Sipp-Eastwood Wood	6 oz.	21″	69° F.	32%	83	116	100
Q	Atwood	Atwood	7 oz.	24″	79° F.	59%	105	175	75

TABLE 13
Winding Tensions
(150 Denier Yarn)

Tension (Grams)	Plant M	Plant N	Total Ends
26 to 30	2		2
31 to 35	18		18
36 to 40	40	4	44
41 to 45	67	6	73
46 to 50	50	20	70
51 to 55	17	38	55
56 to 60	6	61	67
61 to 65	41		41
66 to 70		19	19
71 to 75		10	10
76 to 80		1	1
	200	200	400

This table includes all of the measurements made of the strain on 150 denier rayon yarn in the winding operation in two throwing plants. Two hundred ends were measured in each plant. This table shows the total variations within each plant, the frequency, or number of ends operated within various ranges of tension, and the differences in tension between plants.

TABLE 14
Density of Winding Spools
(150 Denier Yarn)

Density	Plant M	Plant N	Total Ends
31 to 40	16		16
41 to 50	77	11	88
51 to 60	96	40	136
61 to 70	11	117	126
71 to 80		32	32
	200	200	400

This table includes all of the measurements of the density of the winding spools in two throwing plants operating on 150 denier yarn. This table shows the frequency or number of spools of various hardness and the total variations in hardness in each plant.

TABLE 15
Winding Tensions
(100 Denier Yarn)

Tension (Grams)	Plant O	Plant P	Total Ends
11 to 15	1	11	12
16 to 20	38	92	130
21 to 25	92	66	158
26 to 30	54	21	75
31 to 35	14	7	21
36 to 40	1	0	1
41 to 45		2	2
46 to 50		1	1
	200	200	400

This table includes all of the measurements made of the strain on 100 denier yarn in the winding operation in two throwing plants. Two hundred ends were measured in each plant. This table shows the total variations within each plant, the frequency, or number of ends operated within various ranges of tension, and the differences in tension between plants.

TABLE 16
Density of Winding Spools
(100 Denier Yarn)

Density	Plant O	Plant P	Total Spools
11 to 20	2		2
21 to 30	77		77
31 to 40	106		106
41 to 50	15	11	26
51 to 60		40	40
61 to 70		117	117
71 to 80		32	32
	200	200	400

This table includes all of the measurements made of the density of the winding spools in two throwing plants operating on 100 denier rayon yarn. This table shows the frequency or number of spools of various hardness and the variations in hardness and the total variations in hardness in each plant.

TABLE 17

Summary of the General Data Gathered in the Survey of the Twisting or Throwing Operation

Plant No.	Twist	Make of Twisters	Flyers		Length of Yarn Under Strain		Spindle Speed	Temp.	Humidity	Denier of Yarn
			Type	Make	Weight					
M	49	Atwood Single Deck	4 Arm Cam Eccentric	Herr	No. 14 Wire	16"	9200	77° F.	50%	150
N	52	Atwood Double Deck	4 Arm Cam Eccentric	McHale	No. 10 Wire	12"	9800	73° F.	62%	150
O	60	Delahanty	4 Arm Cam Eccentric	Herr	No. 8 Wire	15"	8200	74° F.	31%	100
P	55	Atwood Single Deck	4 Arm Mill Nut	McHale	No. 10 Wire	18"	9200	73° F.	44%	100
Q	58	Atwood Double Deck	4 Arm Cam Eccentric	McHale	No. 8 Wire	15"	9100	79° F.	54%	75

TABLE 18

Twisting Tensions (150 Denier Yarn)

Tension (Grams)	Plant M	Plant N	Total Ends
1 to 5	1		1
6 to 10	70		70
11 to 15	64	3	67
16 to 20	39	29	68
21 to 25	19	86	105
26 to 30	4	42	46
31 to 35	0	19	19
36 to 40	1	11	12
41 to 45	1	7	8
46 to 50	1	3	4
	200	200	400

This table includes all of the measurements made of the strain on 150 denier yarn in the twisting operation in two throwing plants. Two hundred ends were measured in each plant. This table shows the total variations within each plant, the frequency, or number of ends operated within various ranges of tension, and the differences in tension between plants.

TABLE 19

Twisting Tensions (100 Denier Yarn)

Tension (Grams)	Plant O	Plant P	Total Ends
6 to 10	3	20	23
11 to 15	84	74	158
16 to 20	85	62	147
21 to 25	19	26	45
26 to 30	8	13	21
31 to 35	1		1
36 to 40		3	3
41 to 45		2	2
	200	200	400

This table includes all of the measurements made of the strain on 100 denier yarn in the twisting operation in two throwing plants. Two hundred ends were measured in each plant. This table shows the total variations within each plant, the frequency, or number of ends operated within various ranges of tension and the differences in tension between plants.

TABLE 20

Summary of the General Data Gathered in the Survey of the Redrawing Operation

Plant No.	Make of Machines	Length of Yarn Under Strain	Linear Yarn Running Speed (Yards per Minute)		Average Temperature	Average Humidity	Denier of Yarn
			Min.	Max.			
M	Atwood	30"	111	174	73° F.	52%	150
N	Atwood	28"	64	141	72° F.	49%	150
O	Atwood	18"	47	99	79° F.	29%	100
P	Atwood	28"	80	160	70° F.	40%	100
Q	Atwood	19"	95	182	74° F.	48%	75

TABLE 21
Redrawing Tensions
(150 Denier Yarn)

Tension (Grams)	Plant M	Plant N	Total Ends
16 to 20	5		5
21 to 25	52		52
26 to 30	67		67
31 to 35	48	5	53
36 to 40	14	45	59
41 to 45	5	87	92
46 to 50	5	40	45
51 to 55	4	21	25
56 to 60		2	2
	200	200	400

This table includes all of the measurements made of the strain on 150 denier yarn in the redrawing operation in two throwing plants. Two hundred ends were measured in each plant. This table shows the total variations within each plant, the frequency, or number of ends operated within various ranges of tension, and the differences in tension between plants.

TABLE 22
Density of Redrawing Spools
(150 Denier Yarn)

Density	Plant M	Plant N	Total Spools
21 to 30	1		1
21 to 30	82		82
41 to 50	82	6	88
51 to 60	33	137	170
61 to 70	2	56	58
71 to 80		1	1
	200	200	400

This table includes all of the measurements made of the density of the redrawing spools in two throwing plants operating on 150 denier yarn. This table shows the frequency or number of spools of various hardness and the total variations in hardness in each plant.

TABLE 23
Redrawing Tensions
(100 Denier Yarn)

Tension (Grams)	Plant O	Plant P	Total Ends
6 to 10	4		4
11 to 15	23		23
16 to 20	83	8	91
21 to 25	68	32	100
26 to 30	18	21	39
31 to 35	3	11	14
36 to 40	1	3	4
	200	75	275

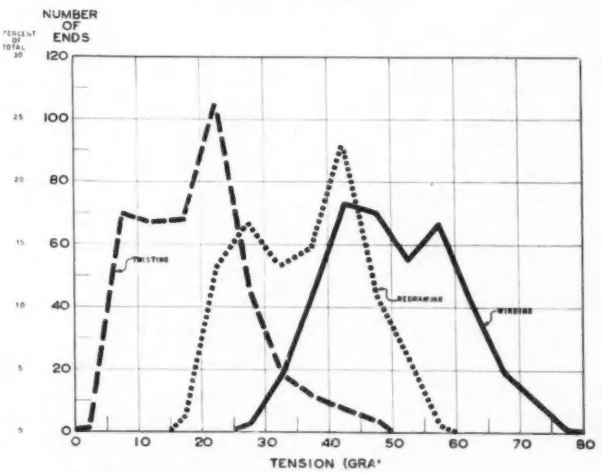
This table includes all of the measurements made of the strain on 100 denier yarn in the redrawing operation in two throwing plants. This table shows the total variations within each plant, the frequency, or number of ends operated within various ranges of tension and the difference in tension between plants.

TABLE 24
Density of Redrawing Spools
(100 Denier Yarn)

Density	Plant O	Plant P	Total Spools
11 to 20	3		3
21 to 30	8		8
31 to 40	35		35
41 to 50	84	6	90
51 to 60	54	137	191
61 to 70	15	56	71
71 to 80	1	1	2
	200	200	400

This table shows all of the measurements made of the density or hardness of the redrawing spools in the throwing plant operating on 100 denier yarn. This table shows the total variations in hardness and the frequency or number of spools of various hardness.

CHART-11
Frequency Distribution of the Winding, Twisting and Redrawing Tensions
Used on 150 Denier Viscose Type Rayon in Two Throwing Plants



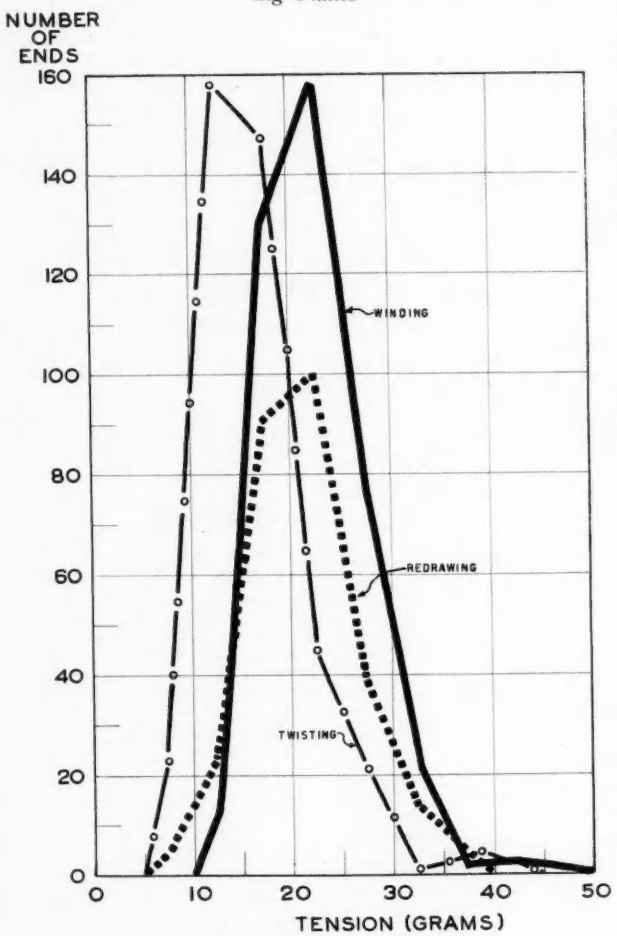
Source: Rayon Crepe Research W.F.M.

This chart includes all of the measurements made of the tension used on 150 denier rayon yarn in the various operations in two throwing plants. It shows the total variations in each operation and the frequency or number of ends operated within various ranges of tension. This chart was plotted from the data in Tables No. 13, 18 and 21.

CHART-12

Frequency Distribution of the Winding, Twisting and Redrawing Tensions

Used on 100 Denier Viscose Type Rayon in Two Throwing Plants



Source: Rayon Crepe Research W.F.M.

This chart includes all of the measurements made of the tension used on 100 denier rayon yarn in the various operations in two throwing plants. It shows the total varations in each operation and the frequency or number of ends operated within various ranges of tension. This chart was plotted from the data in Tables No. 15, 19 and 23.

TABLE 25

Tension on 75 Denier Yarn

Tension (Grams)	*Plant Q*			*Total Ends*
	Winding	*Twisting*	*Redrawing*	
6 to 10		155		155
11 to 15		38		38
16 to 20	2	6	41	49
21 to 25	12	1	118	131
26 to 30	62		38	100
31 to 35	35		3	38
36 to 40	61			61
41 to 45	20			20
46 to 50	8			8
	200	200	200	600

This table includes all of the measurements made of the tension on 75 denier yarn in the different operations in plant Q. This table shows the total variations in each operation and the frequency or number of ends operated within various ranges of tension.

TABLE 26

Density of Spools (75 Denier Yarn)

Density	*Plant Q*		*Total Spools*
	Winding	*Redrawing*	
21 to 30	2		2
31 to 40	38	5	41
41 to 50	114	113	227
51 to 60	48	79	127
61 to 70		3	3
	200	200	400

This table shows all the measurements made of the density or hardness of the spools in the winding and redrawing operation in plant Q. This table shows the total variations in hardness and the frequency or number of spools of various hardness.

III—A Comparison of the Winding Qualities of Rayon Skeins in a Rayon Producing Plant and a Throwing Plant

INTRODUCTION

THE purpose of this investigation was to determine the effect of existing methods of handling skeined rayon yarn, from the time it leaves the dryers in the rayon producing plants until it is used in the throwing plants, upon its winding quality and winding efficiency.

Claims were made to the Rayon Crepe Research Committee that rayon producers enjoy better winding because their skeins are taken directly from the dryers and wound with a very small amount of handling; whereas the skeins ordinarily wound by throwsters were previously inspected, doled (customary twisted condition as received in the market), compressed into bundles and packed into cases in the rayon manufacturing plants, and sometimes stored long period, after which they were later soaked, extracted and dried in the throwing plants. This survey was made to determine whether yarn taken directly from the dryers of the rayon producing plant wound better than yarn which had been packed into the usual 10 pound bundles.

Since this survey was made in only one rayon producing plant and in one throwing plant, it is not very representative of the industry but it is nevertheless a fair comparison of the winding qualities of skeined rayon yarn and the winding process in two plants.

There are numerous factors which influence the production of the winding operation but it was only possible to study the following in this survey:

1. Speed of winding.
2. Number of breaks during winding.
3. The strain or tension on the yarn during winding.

This investigation is not related to the rayon crepe problems studied in this research. It originated from a discussion regarding the effects of existing methods of handling and packing rayon skeins upon the winding quality and winding efficiency.

This investigation is complete in itself and the conclusions are based on the facts as found.

The results should be of interest to rayon yarn producers and consumers of skeined rayon yarn.

SUMMARY

Claims were made to the Rayon Crepe Research Committee that the existing methods of handling and packing rayon skeins affected their winding quality and winding efficiency. It was alleged that skeins which are taken directly from the dryers in the rayon producing plants ran better in winding than those which are inspected, doled, compressed, packed, sometimes stored long periods, then soaked and wound in the throwing plants.

This investigation was made to determine—

1. The differences in the winding quality of skeins which were taken directly from the dryer of a rayon producing plant and skeins which were packed in the usual 10 pound bundles.

2. The differences in the normal winding operation in a rayon producing plant and a throwing plant.

A comparison was made of—

1. The number of breaks in winding.
2. The strain exerted on the yarn during winding.
3. The linear speed of the yarn in winding.

400 skeins from a dryer of a rayon producing plant and 400 skeins taken from packed bundles were wound in this survey. The skeins were divided into groups and wound as follows:

Group No. 1. 200 skeins from the dryer of the rayon producing plant were wound, untreated, in the rayon producing plant under their normal conditions.

Group No. 2. 200 skeins from a packed case were wound, untreated, in the rayon producing plant under their normal conditions.

Group No. 3. 100 skeins from the dryer of the rayon producing plant were wound, untreated, in the throwing plant under their normal conditions.

Group No. 4. 100 skeins from the dryer of the rayon producing plant were soaked and wound in the throwing plant under their normal conditions.

Group No. 5. 100 skeins from a packed case were wound, untreated, in the throwing plant under their normal conditions.

Group No. 6. 100 skeins from a packed case were soaked and wound in the throwing plant under their normal conditions.

The facts found in this work showed the following:

1. In the rayon producing plant the yarn from the dryer ran slightly better than the yarn from the packed case.

2. In the throwing plant the yarn from the dryer ran better, in the untreated state, but after being soaked both the yarn from the dryer and from the packed case ran exactly the same.

3. The best running yarn was that which was soaked and wound in the throwing plant.

4. The speed of winding and the tension or strain exerted on the yarn during winding was practically the same in both plants.

5. Since throwing plants soak most of their yarn they enjoy better winding than the rayon producers. The data in this investigation indicates that the present method of handling rayon skeins between the dryers in the rayon producing plants and the winding operation in the throwing plants does not affect the winding quality of the skeins.

Description of Yarn

The rayon yarn used in this survey was first quality, 150 denier, viscose type, bright luster, in skeins.

Source of Yarn and Treatment

Eight hundred skeins were taken at random by the Research Fellow from the regular production of a rayon producing plant, 400 of which were taken directly from the dryer and 400 from a packed case ready for shipment.

Four hundred of the 800 skeins were wound in a rayon producing plant and 400 were wound in a throwing plant. The skeins that were wound in the throwing plant were shipped from the producing plant to the throwing plant in a special container in which the skeins were laid perfectly flat. This eliminated the necessity of twisting them together.

The skeins were divided into 6 groups, identified and wound as follows:

Group No. 1. 200 skeins from the dryer of the rayon producing plant were wound in the rayon producing plant, without any previous treatment.

Group No. 2. 200 skeins from a packed case were wound in the rayon producing plant without any previous treatment.

Group No. 3. 100 skeins from the dryer of the rayon producing plant were shipped to the throwing plant in a special container and were wound without any previous treatment.

Group No. 4. 100 skeins from the dryer of the rayon producing plant were shipped to the throwing plant in a special container and were soaked and wound.

Group No. 5. 100 skeins from a packed case shipped to the throwing plant in regular 10 pound bundles, were wound without any previous treatment.

Group No. 6. 100 skeins from a packed case were shipped to the throwing plant in regular 10 pound bundles and were soaked and wound.

The yarn taken from the dryer of the rayon producing plant was allowed to cool thoroughly and was then suspended on poles along with the yarn from the packed case and they were both placed in the winding room and permitted to assume the same atmospheric balance before being wound.

The groups of yarn which were previously soaked before being wound in the throwing plant were removed from the dryer of the throwing plant, allowed to cool several hours and then were suspended on poles in the winding room along with the yarn which received no treatment and all the groups were allowed to assume the same atmospheric balance before being wound.

Specifications and Equipment Used

No method of winding was recommended to either plant but it was suggested that they both use the same procedure as they did in winding regular production. The methods used were as follows:

	Rayon Mfg. Plant	*Throwing Plant*
Make of Winders	Sipp-Eastwood	Atwood
Make of Swifts	Sipp-Wire	Atwood-Wire
Width of Swift Cradles	3½"	3⅝"
Weight on Axles of Swifts	13 ounces	12 ounces
Length of Yarn Under Strain	22"	19½"
Linear Running Speed of Yarn (Yds. per Minute) Minimum	128	120
Maximum	177	175

TABLE 27
Total Number of Breaks

	Rayon Plant		*Throwing Plant*			
	Group No. 1	*Group No. 2*	*Group No. 3*	*Group No. 4*	*Group No. 5*	*Group No. 6*
Breaks	43	46	18	12	31	12
Percent	21.5%	23.0%	18.0%	12.0%	31.0%	12.0%
Number of Skeins Which Broke One or More Times						
Skeins	21	38	17	12	18	12
Percent	10.5%	19.0%	17.0%	12.0%	18.0%	12.0%
Number of Skeins Which Broke More Than Once						
Skeins	4	8	1	0	3	0
Percent	2.0%	4.0%	1.0%		3.0%	
Number of Skeins Which Broke More Than Twice						
Skeins	3	0	0	0	1	0
Percent	1.5%				1.0%	
Number ofSkeins Which Broke More Than Five Times						
Skeins	2	0	0	0	1	0
Percent	1.0%				1.0%	

TABLE 28
Winding Tension

	Percent of Skeins					
Tension (Grams)	*Group No. 1*	*Group No. 2*	*Group No. 3*	*Group No. 4*	*Group No. 5*	*Group No. 6*
16 to 20					8.0%	3.0%
21 to 25	9.0%	14.5%	10.0%	14.0%	29.0%	19.0%
26 to 30	50.5%	52.0%	42.0%	34.0%	31.0%	44.0%
31 to 35	30.0%	29.0%	22.0%	31.0%	20.0%	20.0%
36 to 40	9.5%	3.5%	22.0%	13.0%	9.0%	8.0%
41 to 45	1.0%	1.0%	2.0%	6.0%	3.0%	4.0%
46 to 50			2.0%	2.0%		2.0%

This table shows:

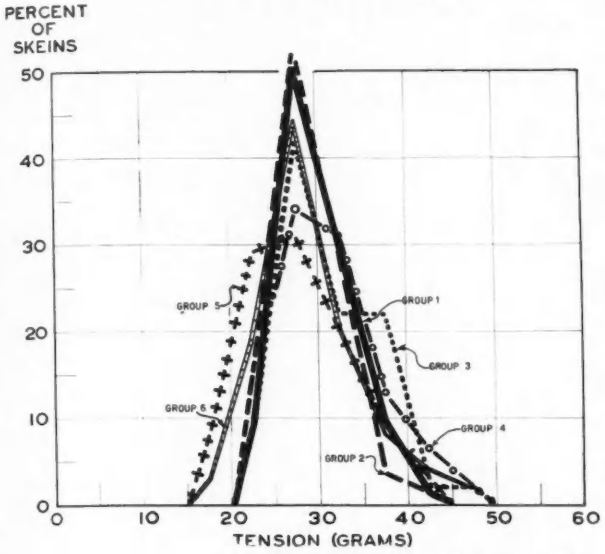
1. The tension on the yarn in winding in both the rayon producing plant and the throwing plant;
2. The frequency, or number of ends operated within various ranges of tension;
3. The total variations in tension.

DISCUSSION OF RESULTS

This survey showed that the yarn from the dryer of the rayon producing plant (Group No. 1) ran a little better than the yarn from the case (Group No. 2) when these groups were wound in the rayon producing plant, although the strain or tension on both groups was nearly the same and the running speed of the yarn was practically the same. This survey indicates that it would be advantageous for the rayon producers to wind yarn taken directly from their dryers instead of the packed cases.

CHART-28

Comparative Frequency Distribution of the Strain on the Yarn During Winding



Source: Rayon Crepe Research W.F.M.

This chart includes all the measurements made of the tension on the yarn in the rayon producing plant and throwing plant. It shows the total variations in tension in each group and the frequency or number of skeins operated within various ranges of tension. This chart was plotted from the data in Table No. 28.

This survey also showed that in the throwing plant the yarn directly from the dryer of the rayon producing plant (Group No. 3) ran better in the untreated state than the yarn from the packed case (Group No. 5).

It will be observed that the yarn directly from the dryer of the rayon producing plant (Group No. 4), and the yarn from the packed case (Group No. 6), after being soaked and wound in the throwing plant ran the same and had the least number of breaks.

Since throwing plants only wind a very small percentage of their production without soaking and there was no difference in the running quality of the yarn directly from the dryer of the rayon producing plant and from a packed case after being soaked in the usual manner in a throwing plant, it would be no advantage to the throwsters to receive yarn directly from the dryers of the rayon producing plants.

From a production standpoint this survey showed that the throwster enjoys better winding than the rayon producer provided that the yarn is soaked before being wound.

It is interesting to note that the total number of breaks in the 400 skeins wound in the rayon producing plant was the same as the total number of breaks in the 400 skeins wound in the throwing plant.

In Groups No. 1 and No. 5, the total number of breaks occurred in comparatively few skeins. From a practical viewpoint, it is more advantageous to have one break each in ten skeins than ten breaks in one skein because after a skein breaks several times, it is liable to become somewhat tangled and require more of the operator's time with each succeeding break.

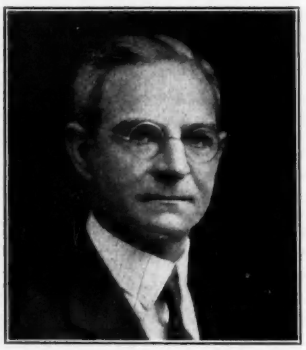
The strain on the yarn during winding was practically the same in both plants. This is shown in table No. 28 and graphically in the frequency distribution curves of the tension (Chart No. 28).

The speed of winding was practically the same in both plants.

CONCLUSIONS

1. In the rayon producing plant the yarn from the dryer ran slightly better than the yarn from the packed case.
2. In the throwing plant the yarn from the dryer ran better, in the untreated state, but after being soaked, both the yarn from the dryer and that from the packed case ran exactly the same.
3. The best running yarn was that which was soaked and wound in the throwing plant.
4. The speed of winding and the tension or strain exerted on the yarn during winding was practically the same in both plants.
5. Since throwing plants soak most of their yarn they enjoy better winding than the rayon producers. The data in this investigation indicates that the present method of handling rayon skeins between the dryers in the rayon producing plants and the winding operation in the throwing plants does not affect the winding quality of the skeins.

ANNUAL MEETING AND CONVENTION



ELMER C. BERTOLET
General Chairman

ARRANGEMENTS

Under the direction of Elmer C. Bertolet as general chairman and Alban Eavenson as vice-chairman, details of arrangements for the Annual Meeting and Convention are rapidly being completed to assure a successful gathering for the members of the Association. All of the various committees have been performing their duties in a manner bound to meet with the approval of those attending the meeting.

ALBAN EAVENSON
Vice-Chairman

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Member, Entertainment Committee

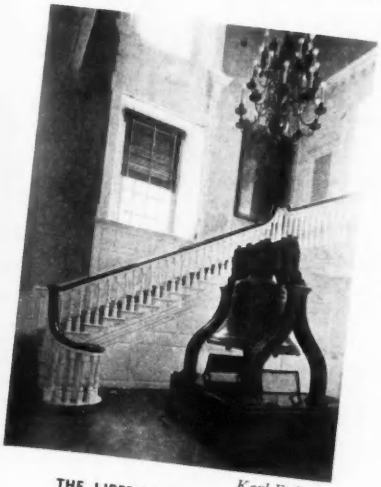
ENTERTAINMENT

The Entertainment Committee has engaged excellent talent and one of Philadelphia's finest orchestras for entertainment on Friday and Saturday nights.

Arrangements have also been made for the entertainment of ladies who accompany members, including bridge and a special luncheon. A number of ladies from Philadelphia will act as their hostesses.

A. W. EDWARDS
Member, Entertainment Committee

DECEMBER 3rd and 4th, Philadelphia, Pa.



Karl F. Lutz

THE LIBERTY BELL is housed in Independence Hall.

"The Convention City"

Annual Meeting and Convention

Philadelphia, Pa.

December 3 and 4

The Photo Illustrators

INDEPENDENCE HALL, in which the Declaration of Independence and Constitution of the United States were signed, is located at Sixth and Chestnut Streets and is open to visitors daily, including Sundays, between the hours of 9:00 A. M. and 5:30 P. M.

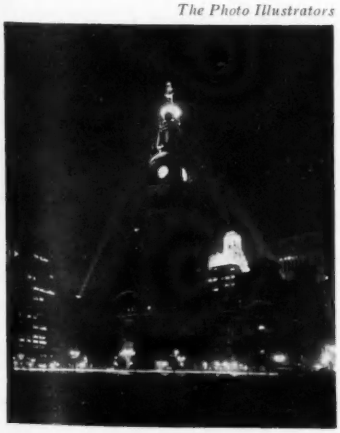
Penna. Dept. of Highways

CARPENTER'S HALL, the meeting place of the First Continental Congress, is located at the head of a small court running south from Chestnut Street, between Third and Fourth Streets. It may be visited daily, except Sundays, between 9:00 A. M. and 4:00 P. M.

Penna. Dept. of Highways

BETSY ROSS HOUSE, in which the first American flag was made, is at 239 Arch Street and may be visited daily, including Sundays and holidays between the hours of 9:00 A. M. and 5:00 P. M.

The Photo Illustrators



Left—CITY HALL, covering an entire city block, lies at the intersection of Broad and Market Streets, the Broadway and 42nd Street of the Quaker City. The tower of the building is approximately 548 feet in height, with a clock 26 feet in diameter. It is surmounted by a gigantic statue of William Penn. The building houses the Municipal offices. The tower, which gives an excellent view of the city, is open to visitors between 9:00 A. M. and 3:30 P. M. Monday to Friday, inclusive, and between 9:00 and 11:30 A. M. on Saturdays.

Below—THE PARKWAY connects the center of the city with Fairmount Park. Facing this Parkway are such prominent structures as the Public Library, the Rodin Museum, the Franklin Memorial and Franklin Institute Museum and at one end, one of the finest art galleries in existence.

The Photo Illustrators

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